TECHNICAL REPORT

NO. T94-15

CONCEPT EVALUATION: INTER-INDIVIDUAL VARIATION AS THE BASIS FOR OPTIMIZING NUTRITIONAL SUPPORT FOR SPECIAL OPERATIONS FORCES (SOF) SOLDIERS

by

Catherine L.V. Gabarée, Ph.D., MAJ Cecilia D. Thomas, M.Ed., R.D.,
Tanya E. Jones, M.S., R.D., Reed W. Hoyt, Ph.D.
and COL E. W. Askew, Ph.D.

May, 1994

U.S. Army Research Institute of Environmental Medicine
Natick, Massachusetts 01760-5007

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
Concept Evaluation: Inter-Individual Variation as the Basis for Optimizing Nutritional Support for Special Operations Forces (SOF) Soldiers

5. FUNDING NUMBERS
STO 3V
WU 150
CC 4430385VB4A00

6. AUTHOR(S)
Gabaree, C.L.V., C.D. Thomas, T.E. Jones, R.W. Hoyt, and E.W. Askew

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Research Institute of Environmental Medicine
Natick, MA 01760-5007

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Research, Development, Acquisition and Logistics Command
Fort Detrick
Frederick, MD 21702-5012

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release
Distribution is unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
Part I. Substrate utilization during exercise and the factors which may effect intra-individual and inter-individual variation in substrate utilization are reviewed and discussed. Customization of nutritional support for the individual Special Operations Forces (SOF) soldier during mission deployment may be feasible and recommended for optimal physical performance in the field.

Part II. Physical characteristics which impact on physical performance (age, height, weight, surface area, percent body fat, lean body mass) and maximal oxygen consumption ($\dot{V}O_2max$) of (SOF) soldiers were compared to the same characteristics in non-SOF U.S. Army soldiers. Using these physical characteristics as criteria, SOF soldiers are a statistically distinct sub-group within the U.S. Army.

Physical activity and nutrition of SOF soldiers was assessed. Results indicate that SOF soldiers are highly active and that both occupational and recreational activities are very diverse. In the field, SOF soldiers consume less than 3000 $kcal \cdot da^{-1}$. Additionally, carbohydrate consumption in the field approximates 300 $grams \cdot da^{-1}$ which is less than the 400 $g \cdot day^{-1}$ recommended by the Committee on Military Nutrition.

14. SUBJECT TERMS
Special Operations Forces (SOF), substrate utilization, physical characteristics, maximal oxygen consumption ($\dot{V}O_2max$), habitual physical activity, nutrient intake

15. NUMBER OF PAGES
62

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

TABLE OF CONTENTS

APPENDIXES

LIST OF FIGURES

LIST OF TABLES

BACKGROUND

The U.S. Army John F. Kennedy Special Warfare Center and School (JFKSWCS), Fort Bragg, NC, initiated a program, Non-material Individual Enhancement for SOF Soldier (NIESS), to improve the individual SOF soldier's physical and mental capacities during preparation and performance of individual and group tasks related to mission requirements in an operational environment (Appendix A). The requirement for an Individual Operational Rations project is outlined in the Mission Need Statement for Non-Material Individual Enhancement for SOF Soldiers. The Food Engineering Directorate, U.S. Army Natick Research Development and Engineering Center (NRDEC), with assistance from the U.S. Army Research Institute of Environmental Medicine (USARIEM) and Soldier Science Directorate, was requested by JFKSWCS to draft the scope of work for this project. In January 1992 the U.S. Special Operations Command approved and funded the SOF Individual Operational Ration Technology Base project (FY 92-94) (Appendix A). The information presented in this report provides the foundation for the investigation of metabolic variation between individuals as the basis for differences in nutritional requirements. Part I develops a rationale from the scientific literature on metabolic variation to support the development of a ration tailored to the individual needs of SOF soldiers; Part II is an evaluation of background data on the physical characteristics, physical activity, and performance capabilities of SOF soldiers.

ACKNOWLEDGEMENTS

The authors would like to thank the staff of the Altitude Physiology and Medicine Division, USARIEM, for their efforts during the studies cited herein, Susan H. Mutter, GEO-Centers, Inc., for her assistance in analyzing the nutrition data, Karen L. Speckman for her excellent suggestions and efforts in editing this document, and particularly the volunteers who participated in these studies for their fine efforts and outstanding cooperation.

EXECUTIVE SUMMARY

PART I

The variables which effect substrate utilization during exercise are reviewed and discussed. Carbohydrate and fat are the principle energy substrates. The predominant substrate utilized in healthy individuals depends on exercise intensity and duration, previous diet, and physical training. Under conditions of inadequate carbohydrate consumption, the body shifts from a carbohydrate to a fat predominant metabolism. Since inadequate carbohydrate intake reduces body stores of glycogen and the reduced stores of glycogen, in turn, impairs physical performance, an important strategy in improving physical performance during deployment may be improving carbohydrate intake. It remains to be seen if all SOF soldiers respond similarly to increased carbohydrate provision.

PART II

Physical characteristics which impact on physical performance (age, height, weight, surface area, percent body fat, lean body mass) and aerobic exercise power ($\dot{V}O_2max$) of Special Operations Forces (SOF) soldiers presented in the scientific and technical literature are summarized and compared to the same parameters in non-SOF U.S. Army troops. Using these anthropometric and $\dot{V}O_2max$ data as criteria, SOF soldiers are a statistically distinct sub-group within the U.S. Army.

Physical activity and nutrition questionnaires were administered to 19 SOF soldiers. SOF soldiers responding to these questionnaires were highly active ($\approx$304 $kcal \cdot kgBW^{-1} \cdot day^{-1}$). Occupational and recreational activitvies were very diverse. The results of the nutrition questionnaire are in concert with previous findings indicating that soldiers in the field do not consume more than 3000 $kcal \cdot day^{-1}$ and that carbohydrate consumption approximates 300 $grams \cdot day^{-1}$ which is less than the amount recommended by the Committee on Military Nutrition.

Analysis of the respiratory and blood metabolite data from two previous USARIEM studies in which SOF soldiers participated as volunteers demonstrated considerable variation between individuals evidenced by the coefficient of variation within groups.

PART I: THEORETICAL RATIONALE

INTRODUCTION

The primary fuels, or energy substrates, used by the body for energy production are carbohydrates and fats. The relative contributions of these substrates are affected by health, physical training, prior diet, relative exercise intensity and exercise duration (2, 56). It is generally accepted that the predominant roles for proteins are as enzymes, or as contractile or structural proteins; however, proteins may be used as a source of energy under some circumstances (9, 36, 52). Substrate utilization has been studied in great detail and nutritional recommendations for enhancement of physical performance abound. These recommendations are generally based on the mean energy expenditures and mean substrate use of experimental groups. The advisability of tailoring nutrition to the individual as well as to the task for optimization of physical performance has not been explored. The pivotal issue in clarifying the advisability of such a practice is identification of sufficient variation between individuals in substrate utilization during exercise and recovery. To our knowledge, no investigation has focused on variation between individuals with the intent of optimizing nutrition. Indeed, there exists relatively little data on metabolic variation between individuals.

Special Operations Forces (SOF) missions during peace and war are highly variant with regard to tasks, environment, duration and intensity. SOF soldiers are often deployed for several days without resupply and, so, must carry all their supplies and equipment for mission requirements. Since missions often involve arduous physical activity and prolonged periods carrying heavy loads, nutritional requirements are increased at a time when food intake is frequently decreased (34). Inadequate nutrition can compromise physical performance and, hence, the successful completion of the mission.

The scientific validity of tailoring nutrition to the individual should be based on research findings demonstrating significant variation between individuals in substrate utilization during exercise and recovery. Significant variation between individuals in substrate utilization would indicate different nutritional requirements for optimization of physical performance, particularly during mission deployment.

It is the purpose of Part I of this paper to present a theoretical rationale for the investigation of inter-individual variation in substrate utilization as the basis for optimizing the nutrition of SOF soldiers during deployment.

FUELS USED FOR ENERGY PRODUCTION

The human organism requires energy for the biological activities it performs both at rest and during physical exercise. Production of metabolic energy requires fuel which humans derive from food. The estimated amount of energy expended by a 75 kg man lying at rest for a 24-hour period is approximately 1800 kcal (39). However, resting energy expenditures vary between individuals (13, 14) and increase with increasing lean body mass (13, 45). The requirement for fuel, or energy substrate, increases as physical activity increases and is directly proportional to the amount of metabolic work performed. The amount of energy required by this same 75 kg man at rest can double or triple as physical activity increases. Metabolic work may be quantified in terms of liters of oxygen consumed (1 liter of O_2 consumed $\approx$ 5 kcal). The amount of oxygen consumed by individuals to complete a given task may differ with differences in work efficiency, total muscle mass involved, and, in cases of weight-bearing exercise, total body mass involved. Fuel for energy is provided by carbohydrates, fats, and proteins. However, these three energy substrates do not contribute equally to energy production. The proportional requirement of each substrate changes with the changing demands placed on the organism. It is generally accepted that carbohydrates and fats are the principle food fuels. However, there is some recent evidence (9,36) to support greater utilization of protein as an energy substrate during physical exercise than was previously thought. Even so, this greater contribution is thought to be significantly less than that of carbohydrate and fat. The relative contribution of the principle food fuels in healthy individuals during exercise is influenced by several factors: intensity and duration of the exercise, previous diet, and the type and degree of physical training.

The Effects of Exercise Intensity and Duration on Substrate Use

At rest, carbohydrates and fats contribute fairly equally as fuels for energy, however, during exercise the amount and proportion of fuels changes. Generally, with increasing exercise intensity, there is a greater dependence on carbohydrate as energy substrate and with prolonged exercise, there is an increasing dependence on fat metabolism. At every level of exercise, however, there is a combination of fuels utilized for energy. Figure 1 is a graphical representation of the relative contributions of carbohydrate (CHO) and fat to total energy expenditure during exercise. As exercise is prolonged, carbohydrate stores are progressively reduced and the relative contribution of fat increases.

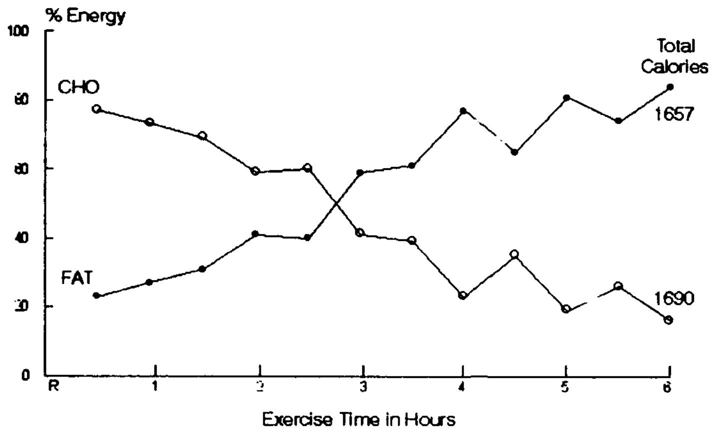

FIG. 1. Contributions of carbohydrate (CHO) and fat during exercise calculated from the respiratory exchange ratio (R= $\dot{V}CO_2$ / $\dot{V}O_2$) (with permission from: Edwards et al., 1934)

An advantage in using predominantly carbohydrates for energy is the immediacy of the response. Carbohydrate is stored in the muscle cell as glycogen, and so, provides a readily available source. Another advantage of carbohydrate is that carbohydrates may provide energy without adequate oxygen. The practical consequence then, is that carbohydrate may provide an immediate food fuel that may be used even when adequate oxygen is not available to the muscle cell. It takes time for additional oxygen to be inspired and transported to the muscle cell. So, at the initiation of exercise, before the depth and rate of breathing increases, the muscle cell depends on available intracellular stores for energy. Additionally, in physical tasks requiring explosive energy, eg. lifting a heavy object or a short run at high speed, the body depends primarily on carbohydrate as a fuel. In these situations when carbohydrate is combusted for energy without adequate oxygen, metabolic by-products, particularly lactate, are produced. The accumulation of lactate in the muscle cell and in the blood stream, limits further performance. If an adequate supply of oxygen is available to the tissue, the carbohydrate may be completely oxidized. This results in the production of more energy, however, the energy production occurs at a slower rate permitting sustained but lower intensity exercise. Stores of carbohydrate are limited and deplete rapidly. The storage form of carbohydrate, glycogen, is found primarily in the liver and muscle and represents only 2-5% of the body's energy

reserves. Stored glycogen may provide up to 2000 kcal of energy while body fat may provide up to 100,000 kcal (2). Fat is by far the predominant form of stored energy. Unlike carbohydrate, the combustion of fat to provide energy requires an adequate supply of oxygen to the tissues. Fat as a substrate costs more oxygen per unit of energy yield. This reliance on oxygen and the intricate biochemical pathways for the metabolism of fat, slow the rate at which energy becomes available. During prolonged exercise (3-6 hours), fat metabolism predominates (Figure 1).

The transition from a carbohydrate to a fat predominant metabolism permits the continuation of exercise by using abundant fat reserves. However, the intensity of exercise is decreased during fat predominant metabolism and, as exercise continues (2-3 hours), liver and muscle glycogen stores are reduced. As previously stated, glycogen reserves are limited and are depleted before fat stores. Once intramuscular glycogen stores are reduced, there is an increased reliance on blood glucose to provide carbohydrate for fuel. At this point during prolonged exercise, blood glucose begins to decline. The depletion of available glucose, including glycogen and blood glucose, is the principle limiting factor in prolonged exercise. It would appear, then, that increasing glucose availability during exercise or immediately after exhaustion from exercise would have a favorable effect. Research by Christensen and Hansen (10) has shown that increasing carbohydrate availability by dietary manipulation prior to prolonged exercise significantly increases exercise time. Additionally, in the same investigation, the administration of glucose to subjects immediately after exhaustion from prolonged exercise restored blood glucose, within 15 minutes, to a level that enabled the subjects to continue exercising for an additional hour. It has been demonstrated in more recent research that carbohydrate ingestion during prolonged exercise delays fatigue by delaying the decline in blood glucose levels (11,12). The consequent increase in exercise time may be as long as 30-60 minutes.

The ability to prolong exercise has obvious implications for the soldier in the field. Successful completion of a mission requires the ability to perform both short-term, intense tasks such as short-distance running, climbing an obstacle, or lifting a heavy object and prolonged tasks such as load carriage or swimming for considerable distances. To support sustained physical activity a soldier requires an adequate amount of calories. Optimal performance, however, requires the adequate proportion of carbohydrate and fat as fuels.

The Effects of Previous Diet on Substrate Use

As previously stated in this paper, Christensen (10) demonstrated that prior diet impacts directly on exercise performance by affecting substrate availability. Subjects who were fed a very high fat diet were unable to exercise as long as subjects who were on a very high carbohydrate diet. The increased availability of carbohydrate enabled subjects on the high carbohydrate diet to exercise about three times longer than the subjects on the high fat diet.

Evidence accumulated during field studies suggests that soldiers usually do not consume more than 3000 kcal per day. This daily intake is not adequate to meet caloric requirements during most field exercises as evidenced by consistent reports of weight loss during field exercises (34). Additionally, and perhaps more importantly, consumption of carbohydrate in the field averages 300 grams per day (33). The Committee on Military Nutrition suggests that a minimum of 400 grams of carbohydrate be consumed each day to enable glycogen resynthesis (41). Recommendations for daily carbohydrate intake for athletes averages 400-450 grams per day (39). Inadequate carbohydrate intake coupled with intense physical activity, as frequently occurs during deployment, results in reduction of liver and muscle glycogen stores. The consequences of reduced glycogen content in the tissues are schematically represented in Figure 2. Performance in a 30-km race was compared under four different conditions. The best performance occurred when initial muscle glycogen stores were the highest. Subsequent performances at progressively reduced initial muscle glycogen levels were progressively impaired. Glycogen depletion results in a reduction in exercise endurance time to exhaustion (11, 12) and a reduction in exercise intensity (5). Glycogen depletion, then, has obvious implications for performance of the SOF soldier in the field.

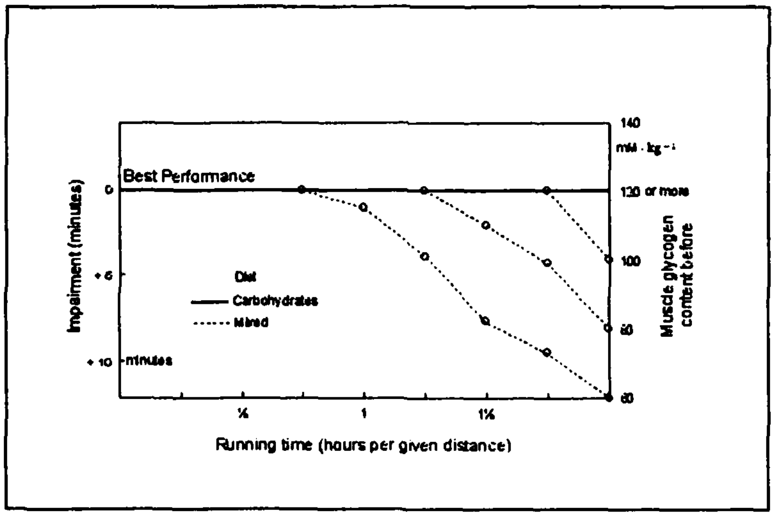

Fig 2. Schematic representation of the impact of decreased initial glycogen content on performance during a 30 km race (running). Differences occurred after the first hour and demonstrated a progressive impairment in performance with decreasing initial muscle glycogen content (with permission from: Astrand, 1986).

Intramuscular and hepatic glycogen stores are highly variable both between individuals and in the same individual at different times. In a recent investigation of U.S. Navy Sea-Air-Land personnel (SEALs), Jacobs et al (33) reported intramuscular glycogen concentrations of 404 ± 124 mmol$\cdot$ kg^{-1} dry muscle weight from the *vastus lateralis*. This represents a coefficient of variation of 31% in this group of similarly trained, highly fit, young men. If individuals have different amounts of initial glycogen levels or utilize glycogen at different rates, carbohydrate supplementation may be more important to some individuals than others for the sustainment of performance.

The Effect of Physical Training on Substrate Use

The impact of physical training on fuel metabolism may be discussed in terms of the principle metabolic pathways for energy production. The study of human metabolism has uncovered two principal processes responsible for energy production. The first process, anaerobic glycolysis, produces energy by breaking down glucose or the storage form of glucose, glycogen. The second process, aerobic oxidation may utilize carbohydrate, fat, or protein as an energy substrate. In addition to adequate fuel for oxidation, the second process, aerobic oxidation, requires an adequate supply of oxygen to be delivered to the cell.

An individual may train primarily the aerobic energy pathways or the anaerobic energy pathways, or both. Aerobic training includes prolonged exercise eg. running, swimming, or rucking. Training the aerobic system increases the capacity to use oxygen and increases the facility for fat utilization as a source of muscular energy. Anaerobic training includes short-term, intense activities such as weight training or sprinting. Anaerobic training increases muscle mass, increases intracellular glycogen stores, and increases the capacity to combust glycogen for activities requiring explosive energy.

PHYSIOLOGICAL VARIATION

Metabolic Variation

Sargent, in an undertaking of vast proportions, developed a hierarchy of physiological variability in young men (48, 49, 50). Variability was divided into three general areas: 1) chemical properties of the internal environment, 2) physical properties of the internal environment, and 3) organ function. In these areas, measurements of inter-individual variability exceeded intra-individual variability. With some exceptions, exercise increased the variability between individuals. Variation in the chemical properties of the internal environment, as defined by the coefficient of variation, ranged from 2.2 to 42.9 percent. Within this area, serum electrolytes demonstrated the smallest variation. Electrolyte stability underlies homeostatic control

of water metabolism. Metabolic by-products, e.g. ketones, demonstrated the greatest variation. The extent to which metabolic variability may impact on nutritional requirements has not been adequately investigated. Pertinent questions to answer are: (1) subjected to the same training and diet, will different individuals require the same substrates in order to perform the same tasks? and (2) are there specific individual requirements for optimal physical performance?

Investigations of the variability between individuals in resting metabolic rate have revealed substantial differences (13, 14). Most of the variation may be accounted for by differences in lean body mass (14, 45), which is metabolically active, while fat mass is significantly less so. SOF soldiers have a significantly higher lean body mass than non-SOF U.S. Army soldiers (Part II). This greater muscle mass generates a higher energy requirement at rest and underlies a greater capacity for physical work. As physical work output increases, the nutritional requirement to supply metabolic fuels also increases.

The idea that some individuals preferentially burn fats or carbohydrates during exercise has persisted for some time. To our knowledge, however, variability in substrate utilization between individuals during exercise and recovery has not been investigated. The acute exercise response may be quite consistent between individuals. At the initiation of exercise, intracellular glycogen stores provide the primary energy substrate; however, within minutes of the initiation of exercise, blood glucose becomes the quantitatively significant substrate for oxidative metabolism. As exercise continues and immediate sources of energy substrate are reduced, mobilization of stored substrate becomes necessary. The metabolically active cell is essentially non-discriminating with regard to substrate for oxidation (43, 45, 46). It is substrate availability rather than specificity that is the factor mediating substrate oxidation. The question then arises, are there significant differences between individuals with regard to substrate availability during exercise and recovery? And, if so, do these differences alter nutritional requirements? Or, can nutrition be manipulated to provide optimal, individual substrate availability?

Factors affecting substrate availability during exercise include prior exercise training (2, 54), diet (26, 31, 46), hepatic and intramuscular glycogen stores (30, 38) and hormonal response (22, 23, 54). Training status and prior diet are highly variable among individuals and impact directly on substrate utilization during exercise (37, 38). Hepatic and intramuscular glycogen stores may be quite variable, even in populations of similar diet and training. As previously discussed in this paper, Jacobs et al. (33) reported glycogen concentrations of 404 ± 124 $mmol \cdot kg^{-1}$ dry muscle weight from the *vastus lateralis,* representing coefficient of variation of 31% in this group of similarly trained, highly fit, young men. It has been clearly demonstrated that glycogen depletion significantly impairs sustainment of performance at higher exercise intensities (4,5) and that carbohydrate ingestion during exercise prolongs exercise performance by increasing glucose availability (1, 11, 12, 25, 32). Variation between

individuals in amounts of stored glycogen or differences in the facility with which individuals utilize stored glycogen may impact on carbohydrate requirements for sustainment of performance. Hormonal response to dietary and exercise stimuli, may vary from individual to individual as discussed later in this paper.

Carbohydrate stored in the muscle and/or liver represents a very small percent of total body energy stores. Most of the body's fuel reserves are stored as fat. Some fat stores are termed "essential". This fat is integrated into nerve and brain tissue, is stored in the marrow of bones, and is integrated into organ tissue. Essential fat is necessary for normal function and is not a readily available source of fuel. The body fat which is available as fuel is stored in adipose tissue both subcutaneously and as padding around internal organs. Essential fat represents 3-4% of total body mass (40). Extreme conditions which compromise maintainence of an appropriate level of essential fat put the individual at risk for rapid loss of lean body mass, injury, loss of normal function, impaired physical performance, and, in the extreme condition , death. SOF soldiers, when deployed, frequently expend more energy during physical activity than they take in as food. In these situations of caloric insufficiency, body fat stores provide a needed energy source. Dependence on fat as the primary fuel in the absence of adequate carbohydrate has a detrimental effect on physical performance. As previously discussed, a fat predominant metabolism during exercise caused by depletion of carbohydrate fuel sources, decreases the potential intensity and duration of physical performance. It appears, then, that provision of adequate carbohydrate to the SOF soldier during deployment is critical to the support of optimal performance.

Hormonal Variation

Hormones compose a diverse array of regulatory molecules whose function is principally to convey signalling information among cells, tissues, or organs. In addition to their pivotal roles in reproduction, growth, development, and homeostatic control of the internal environment, hormones play an important role in energy production, utilization, and storage. In a recent study of inter-individual variability in hormonal response to exercise (54), the response patterns of insulin, C-peptide, adrenocorticotropic hormone (ACTH), aldosterone, and somatotropin were fairly common and stable between individuals. However, although the patterns were similar, the magnitude of the responses varied, as well as the presence of, and length of, an initial lag phase preceding the response. The response patterns of cortisol and testosterone demonstrated significant inter-individual variability. Interestingly, five variant cortisol response patterns were identified independent of $\dot{V}O_2$ max, relative intensity of the exercise performed, the initial level of cortisol, and responses of other hormones. These patterns were repeatable in the same individuals. The lag time in cortisol response represents the time necessary for induction of enzymes involved in the potentiation of lipolysis (22). Inter-individual variation in the lag time may indicate different cortisol effects on exercise-induced lipolysis. ACTH exerts a more direct and

rapid enhancement of lipolysis (22). Although the pattern of ACTH response was consistent, the magnitude of the response and the timing of the characteristic biphasic peaks during submaximal exercise demonstrated considerable inter-individual variation. Differences in the responses of these hormones may indicate inter-individual variation in mobilization of fat reserves.

Genetic Influence on Physical Performance

Genetic factors influence the components of physical performance such as body size, body composition, muscle fiber type, and $\dot{V}O_2$ max (7). In addition to influencing the morphological determinants of physical performance, genetics have a considerable effect on the response to endurance and high intensity intermittent training (7,8). The factors underlying these genetic differences are, as yet, unclear. It is clear, however, that a strong genetic component underlies the potential for physical performance. Investigations are ongoing in the area of genetic polymorphism in the enzymes involved in bioenergetic pathways (8). Tremblay, et al. (51) demonstrated a significant genetic effect on hormonal response to exercise training. The pattern of insulin response to exercise training varied between individuals. Since insulin is the principal hormonal mediator of glucose metabolism, variation between individuals in insulin response to exercise may indicate differences in glucose metabolism. Insulin increases the permeability of the muscle to glucose by increasing the number of glucose transporters in the muscle cell membrane and increasing the rate at which glucose moves through the transporter molecules (35). This increases the amount of glucose available as a substrate within the muscle cell. As research continues in the area of genetic influence on metabolism, specific markers may become available to identify discrete inter-individual metabolic differences.

SUMMARY

1. Total caloric requirement during exercise varies with the amount of metabolic work performed. Metabolic work is commonly quantified by measurement of oxygen consumed. The amount of oxygen consumed by individuals to complete a given task may differ with differences in work efficiency, total muscle mass involved, and, in cases of weight-bearing exercise, total body mass involved.

2. The fractional contributions of carbohydrate and fat as substrates for energy during exercise varies with the intensity and duration of the exercise, previous diet, and physical training. Variation between SOF soldiers in diet and training regimes may induce differences in nutritional requirements for optimal performance during deployment.

3. Variation between individuals in the amounts of glycogen stored in the liver and muscles will affect the availability of carbohydrate as a fuel during exercise. Since the depletion of available carbohydrate for fuel is the principle limiting factor in prolonged exercise, individuals with increased initial glygogen stores have an advantage over individuals with reduced glycogen stores.

4. Genetic factors underlie differences in metabolic and hormonal response to acute exercise and exercise training. It is likely that this genetic polymorphism affects differences between individuals by determining the physical characteristics which determine performance e.g., body size, body composition, muscle fiber type, muscle fiber distribution, and enzymes involved in the bioenergic pathways. Genetic factors also determine trainability, i.e., how well an individual responds to a training program.

CONCLUSION

1. The reasonableness of tailoring rations to the individual SOF soldier during deployment is based on significant variation between individuals in substrate utilization. Theoretically, considerable inter-individual variation may exist in substrate availability during exercise and these differences may impact on nutritional requirements for optimization of physical performance, particularly during prolonged periods of physical activity and inadequate caloric intake as frequently occurs on SOF missions.

PART II: DESCRIPTIVE BACKGROUND INFORMATION

INTRODUCTION

Special Operations Forces (SOF) soldiers are distinguished by their physical prowess. Despite the well-recognized reputation as the elite, professional soldier, there is very little published descriptive data on the physical parameters which underlie the exceptional performance capabilities of the SOF soldier. In order to develop a program to improve the individual SOF soldier's physical and mental capacities during missions, descriptive background information on the physical characteristics, physical activity, and nutrition during deployment of SOF soldiers was necessary. It is the purpose of Part II of this paper to provide this descriptive background information.

The physical characteristics which underlie physical performance include; age, height, weight, surface area, percent body fat, lean body mass, and maximal oxygen consumption ($\dot{V}o_2$max). $\dot{V}o_2$max defines the maximal amount of oxygen (O_2) the body can inspire, transport in the circulation, and utilize in the cells to produce energy. There is wide variation in $\dot{V}o_2$ max among individuals. During prolonged physical work, most of the metabolic energy is produced by aerobic oxidation. The ability to inspire, transport, and utilize large quantities of oxygen is, therefore, essential for the successful completion of prolonged work. $\dot{V}o_2$max may be expressed in absolute terms (liters of O_2 consumed$\cdot$ minute^{-1}) or relative to total body weight (milliliters of O_2 consumed$\cdot$ kg of body weight$^{-1}\cdot$ minute^{-1}). The expression of $\dot{V}o_2$max in relative terms provides an appropriate format to compare individuals. Research has demonstrated that $\dot{V}o_2$max is determined by genetic factors (7). However, proper training may improve $\dot{V}o_2$max 10-20%.

Physical training affects both the performance capacity of the individual and the facility with which substrates are used for energy production. Aerobic training increases the oxidation of fat while anaerobic training increases the utilization of carbohydrates.The parameters which define physical activity include: exercise mode, frequency, intensity, and duration.

METHODS

Physical Characteristics

Physical characteristics and maximal oxygen consumption ($\dot{V}o_2$max) of Special Operations Forces (SOF) soldiers published in the technical and scientific literature were summarized and compared to the same descriptors for non-SOF U.S. Army troops. The data for SOF soldiers was compiled from 4 published studies (15, 27, 34, 42) and includes measurements from 48 SOF soldiers. The data for non-SOF U.S.

Army troops were presented in a comprehensive compilation of aerobic capacity and anthropometric data of U.S. Army personnel (55). The physical characteristics which were included are those which impact on physical performance: age, height, weight, DuBois surface area (19), percent body fat, lean body mass, and $\dot{V}O_2$max. Surface area, lean body mass, and $\dot{V}O_2$max relative to total body weight and lean body mass were calculated from the values for height, weight, percent body fat, and $\dot{V}O_2$max presented in the literature.

Physical Activity

A "Physical Activity Questionnaire" (Appendix D) was designed to ascertain the frequency, intensity, and duration of physical activity of SOF soldiers during regular PT, mission preparation, and mission deployment. The reliability and construct validity of similar self-administered questionnaires for the measurement of habitual physical activity based on a continuous, dichotomous five-point scale response format has been demonstrated (3). Similarly, the Borg scale of perceived exertion (6) is based on the concept that subjective experience during physical exertion is directly related to specific physiological variables including heart rate, minute ventilation, percent $\dot{V}O_2$max, and blood lactate levels.

The questionnaire was administered to 12 members of the 1st Special Forces Group, Fort Lewis, WA and seven members of the 10th Special Forces Group, Fort Devens, MA. The frequency (times per week), intensity (1=very easy, 2=easy, 3=moderate, 4=hard, 5=very hard), and duration (hours per week), of regular physical training (PT), mission preparation, and mission deployment were determined from the responses.

Metabolic Variation

Respiratory data, blood substrates, and blood metabolites from two recent USARIEM studies in which SOF soldiers participated as volunteers (15, 27) were analyzed for variation between individuals. Since the coefficient of variation within groups indicates the amount of variation among individual samples, it represents inter-individual variation. During Study 1 (27), two groups of SOF soldiers performed treadmill running under two environmental conditions: sea level, 50 m (SL) and high altitude, 4300 m (HA). Group 1 exercised at 50% of the previously determined, environmentally specific $\dot{V}O_2$max for 4 hours under both environmental conditions, and Group 2 exercised at 75% of the pre-determined, environmentally specific $\dot{V}O_2$max for 1 hour under both environmental conditions. Respiratory data was collected via open circuit spirometry at intervals throughout the exercise. The amounts of carbohydrate combusted during exercise was calculated from respiratory data (24).

During Study 2 (15), $\dot{V}O_2$max was determined for each of six SOF soldiers at SL. During a subsequent submaximal treadmill running protocol at SL, blood samples

were obtained at rest, at 10, 20, 40, and 60 minutes of exercise and at 4 minutes after the cessation of exercise. After a 15 minute warm-up at 45% $\dot{V}o_2max$, treadmill speed and grade were increased to elicit a relative intensity of 75% $\dot{V}o_2max$ for 45 minutes, then at minute 60, treadmill speed and grade were increased to elicit a relative intensity of 85% and this intensity was maintained until voluntary exhaustion. Free fatty acids (FFA), beta hydroxybutyrate (BOHB), triglycerides (TRIG), and glycerol (GLY) were determined from each blood sample.

Nutrition During Deployment

A food intake questionnaire eliciting the amount and type of food taken on a typical mission was self-administered to 12 soldiers from the 1st SFG, Ft.Lewis, WA and to seven soldiers from the 10th SFG, Ft. Devens, MA. Each participant received written and verbal instructions on how to accurately complete the questionnaire. When the questionnaires were collected, they were checked for proper completion.

Nutrient intakes were calculated by factoring individual food items reported against known macro- and micro-nutrient values. The nutrient factor file included nutrient composition values provided by Natick Research Development and Engineering Center (ration items) and the U.S. Department of Agriculture Nutrient Data Base for Standard Reference (Handbook 8). Data reduction was done on a Digital Equipment Corporation Vax 780 computer using the Computerized Analysis of Nutrients (CAN) system developed by USARIEM (47). Nutrients reported include: energy (kcal), protein (Pro), carbohydrate (CHO), fat, sodium, thiamin, riboflavin, niacin, vitamin B6, iron, magnesium, zinc, calcium, phosphorus, ascorbic acid, folacin, and vitamin A. Mean nutrient intakes were compared to the Military Recommended Dietary Allowances (MRDA) found in AR 40-25 (17).

STATISTICS

Anthropometric and $\dot{V}o_2max$ data were compiled and compared to corresponding data from non-SOF U.S. Army troops (55) using an unpaired t-test. Values for physical characteristics, physical activity, and nutrient data are expressed as $\bar{X} \pm s$ (where, $\bar{X}$ = group mean; s = standard deviation). Inter-individual variation for physical activity, substrate data, and metabolite data was evaluated from the coefficient of variation ($s/\bar{X}$). The coefficient of variation within groups indicates the amount of variation among individual samples.

RESULTS AND DISCUSSION

Physical Characteristics

Physical characteristics and $\dot{V}O_2$ max of SOF soldiers are summarized in Tables 1 and 3, respectively. Pertinent data were available on 48 SOF soldiers who participated as volunteers in four referenced studies (15, 27, 34, 42). The same descriptors for non-SOF U.S. Army troops are summarized in Tables 2 and 4. Data on non-SOF U.S. Army soldiers were available from a comprehensive review of anthropometric data and aerobic exercise power of U.S. Army personnel (55). The data in this review were presented in eight separate groups based on age and gender. Since, there are no active duty females in the Special Operations Forces, only data from the male non-SOF U.S. Army personnel were included in the present comparison. The groups are as follows: (a) basic trainees, n=176, (b) advanced trainees, n=111, (c) stateside personnel, n=199, (d) overseas personnel, n=315, (e) noncommissioned officers > 40 yr, n=168, (f) officers > 40 yr, n=335. SOF soldiers were statistically ($p<0.05$) different from non-SOF U.S. Army troops in: height, weight, surface area, percent body fat, lean body mass, and $\dot{V}O_2$max. $\dot{V}O_2$max and lean body mass directly effect physical performance capabilities. Surface area and percent body fat impact on physical performance largely through their effects on heat storage and thermoregulation.

The significant differences in anthropometric and $\dot{V}O_2$max data of SOF soldiers compared to non-SOF U.S. Army troops (Tables 1, 2, 3, and 4) indicate that SOF soldiers are a statistically distinct sub-group within the military. The greater ($p< 0.05$) LBM and $\dot{V}O_2$max of SOF soldiers compared to non-SOF soldiers indicate that the SOF soldier has a greater capacity for physical work than the non-SOF U.S. Army soldier. Membership in the SOF is voluntary but highly selective. Only extremely fit individuals are capable of the satisfactory completion of the rigorous Special Forces Assessment and Selection (SFAS) Program. Additionally, the SOF soldier is required to maintain a high level of fitness both in garrison and in the field. The high fitness level is maintained by regular PT, occupational tasks and training, and recreational activities.

Random selection of SOF soldiers as test subjects for prolonged studies is precluded by functional dependence on the team as the operational unit. In order to disrupt as few teams as possible, intact teams are frequently engaged as volunteers in research studies. Generalization of the data to all SOF soldiers is therefore limited by the lack of randomized sampling. In order to delimit the constraints imposed by biased sampling techniques, it is recommended that physical variables which directly impact on physical performance be assessed in volunteers participating in future studies of physical performance and compared to a summary of mean values for SOF soldiers. Pertinent physiological variables should include: age, height, weight, percent body fat, lean body mass, DuBois surface area (19), and $\dot{V}O_2$max.

TABLE 1. Anthropometric data of SOF soldiers.

Ref No.	AGE (yr)	HEIGHT (cm)	WEIGHT (kg)	SA (m^2)	%FAT (%)	LBM (kg)
42 n=12	27.9 ±3.3	181.0 ±7.8	84.7 ±12.5	2.04 ±0.19	15.9 ±4.2	70.5 ±9.0
27 n=14	27.3 ±5.7	180.5 ±7.1	79.4 ±11.4	2.00 ±0.17	15.7 ±4.6	66.9 ±9.6
15 n=12	28.8 ±4.1	179.7 ±5.8	80.5 ±10.1	2.00 ±0.14	16.0 ±3.6	67.6 ±8.5
34 n=10	31.9 ±5.4	179.5 ±6.7	81.2 ±9.7	2.00 ±0.15	18.9 ±8.3	65.7 ±1.7
$\bar{X}$±s	29.0* ±1.8	180.2* ±0.6	81.5* ±1.9	2.01* ±0.02	16.6* ±1.3	67.7* ±1.7

SA, DuBois surface area (18)
LBW, lean body weight
$\bar{X}$, mean
s, standard deviation
*, different ($p<0.05$) from non-SOF U.S. Army troops.

TABLE 2. Anthropometric data of non-SOF U.S. Army personnel.

Ref. No.	AGE (yr)	HEIGHT (cm)	WEIGHT (kg)	SA (m^2)	% Fat (%)	LBM (kg)
55** Group a	19.1 ±2.4	na	70.4 ±8.7	-	13.4 ±4.1	60.6 ±6.3
55** Group b	20.8 ±3.4	175.8 ±6.4	69.0 ±9.7	1.85 ±na	15.9 ±4.7	58.0 ±8.2
55** Group c	24.7 ±5.7	176.1 ±6.9	76.8 ±14.2	1.93 ±na	18.6 ±6.2	62.5 ±11.0
55** Group d	23.5 ±7.9	175.0 ±6.5	73.0 ±10.6	1.88 ±na	19.5 ±5.8	58.8 ±8.5
55** Group e	43.4 ±2.7	177.7 ±6.6	83.7 ±12.7	2.01 ±na	26.2 ±4.3	61.8 ±na
55** Group f	43.9 ±3.2	180.2 ±6.8	83.6 ±10.1	2.03 ±na	24.5 ±4.3	63.1 ±na
$\bar{X}\pm s$	29.2 ±11.3	177.0† ±2.1	76.1† ±6.4	1.94† ±0.08	19.7† ±4.9	60.8† ±2.1

SA, DuBois surface area (18)
LBM, lean body mass
na, not available
** Vogel, J.A., J.F. Patton, R.P. Mello, and W.L. Daniels. An analysis of aerobic capacity in a large United States population. J Appl Physiol 60(2): 494-500, 1986. Group a, recruits after 7 weeks of initial entry training; Group b, advanced male trainees after 4 months of of initial and occupational training; Group c, males assigned within the U.S.; Group d, males assigned overseas; Group e, male Non-commissioned officers >40; Group f, male officers >40 (55).
$\bar{X}$, mean
s, standard deviation
†, different ($p<0.05$) from SOF soldiers.

TABLE 3. Maximal aerobic power ($\dot{V}O_2max$) of SOF soldiers in absolute terms ($L \cdot min^{-1}$) and relative to total body weight ($ml \cdot kg^{-1} \cdot min^{-1}$) and lean body mass ($ml \cdot kgLBM^{-1}\ min^{-1}$).

Ref. No.	$\dot{V}O_2max$ ($L \cdot min^{-1}$)	$\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	$\dot{V}O_2max$ ($ml \cdot kgLBM^{-1}\ min^{-1}$)
27	3.94 ± 1.12	46.5 ± 12.7	55.9 ± 3.9
42	4.47 ± 0.63	56.4 ± 4.5	66.9 ± 4.5
15	4.50 ± 0.49	57.0 ± 4.9	67.8 ± 4.4
$\bar{X}$±s	4.30*± 0.26	53.3*± 4.8	63.5*± 5.4

$\bar{X}$, mean
s, standard deviation
*, different ($p<0.05$) from non-SOF U.S. Army troops.

TABLE 4. Maximal aerobic power ($\dot{V}O_2max$) of non-SOF U.S. Army soldiers in absolute terms ($L \cdot min^{-1}$) and relative to total body weight ($ml \cdot kg^{-1} \cdot min^{-1}$) and lean body mass ($ml \cdot kgLBM^{-1}\ min^{-1}$).

Ref. No.	$\dot{V}O_2max$ ($L \cdot min^{-1}$)	$\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	$\dot{V}O_2max$ ($ml \cdot kgLBM^{-1}\ min^{-1}$)
55** Group a	3.76 ± 4.30	53.6 ± 4.4	62.3 ± 4.3
55** Group b	3.58 ± 0.45	52.3 ± 5.0	61.7‡ ± na
55** Group c	3.51 ± 0.44	46.9 ± 7.1	56.2‡ ± na
55** Group d	3.75 ± 0.45	51.9 ± 6.0	63.8‡ ± na
55** Group e	3.04 ± 0.51	36.7 ± 5.5	49.2‡ ± na
55** Group f	3.38 ± 0.50	40.6 ± 6.2	53.6‡ ± na
$\bar{X} \pm s$	3.50† ± 0.27	47.0† ± 7.0	57.8† ± 5.8

** Vogel, J.A., J.F. Patton, R.P. Mello, and W.L. Daniels. An analysis of aerobic capacity in a large United States population. J Appl Physiol 60(2): 494-500, 1986. Group a, recruits after 7 weeks of initial entry training; Group b, advanced male trainees after 4 months of of initial and occupational training; Group c, males assigned within the U.S.; Group d, males assigned overseas; Group e, male Non-commissioned officers >40; Group f, male officers >40 (55).

‡ , standard deviation not available

na, not available

$\bar{X}$, mean

s, standard deviation

†, different ($p<0.05$) from SOF soldiers.

Physical Activity

Data from the physical activity questionnaire administered to 19 SOF soldiers clearly indicate that the SOF soldiers in these groups were highly active. The frequency (times per week), intensity (1-5 scale), and duration (hours per week) of physical activity during regular PT and mission preparation are presented in Appendix B and summarized in Figure 1. The responses of the 1st and 10th groups for all the activity categories: regular PT, mission preparation, and deployment, were similar and there were no differences ($p<0.05$) between regular PT and mission preparation for the two groups. The mean response for mission duration was 11.3 ± 7.1 days. Intensity for missions was reported to be 3.5 ± 0.6, where, 3 = moderate and 4 = hard. There was considerable variability in the responses for frequency, intensity, and duration of physical activity during deployment. This wide variation reflects the widely variant physical demands of different types of missions, e.g., direct action, reconnaissance.

In a study of physical activity in college students, Dishman, et al (18) defined three criterion groups based on weekly energy expenditure: 1) highly active ≥ 280 $kcal \cdot kgBW^{-1} \cdot wk^{-1}$, 2) low active ≥ 245 $kcal \cdot kgBW^{-1} \cdot wk^{-1}$, and 3) inactive < 245 $kcal \cdot kgBW^{-1} \cdot wk^{-1}$. Based on age, gender, surface area, and reported physical activity, the predicted mean energy expenditure for the two groups of SOF soldiers is 304.3 $kcal \cdot kgBW^{-1} \cdot wk^{-1}$ (≈ 3638 $kcal \cdot da^{-1}$). This energy expenditure clearly places these SOF soldiers in a highly active category. Professional and recreational activities reported by these soldiers are widely varied and include both aerobic and anaerobic activities. The inclusion of a wide variety of activities is a training plan often employed by coaches. Although sport-specific training is essential for the development of the athlete, the inclusion of varied activities, a practice known as cross-training (X-training), helps to prevent staleness and, more importantly, encourages development of varied muscle groups. The development of many muscle groups underlies versatility in physical performance and is somewhat protective against injury. Conversely, overdevelopment of specific muscle groups may lead to muscle imbalance and susceptibility to injury.

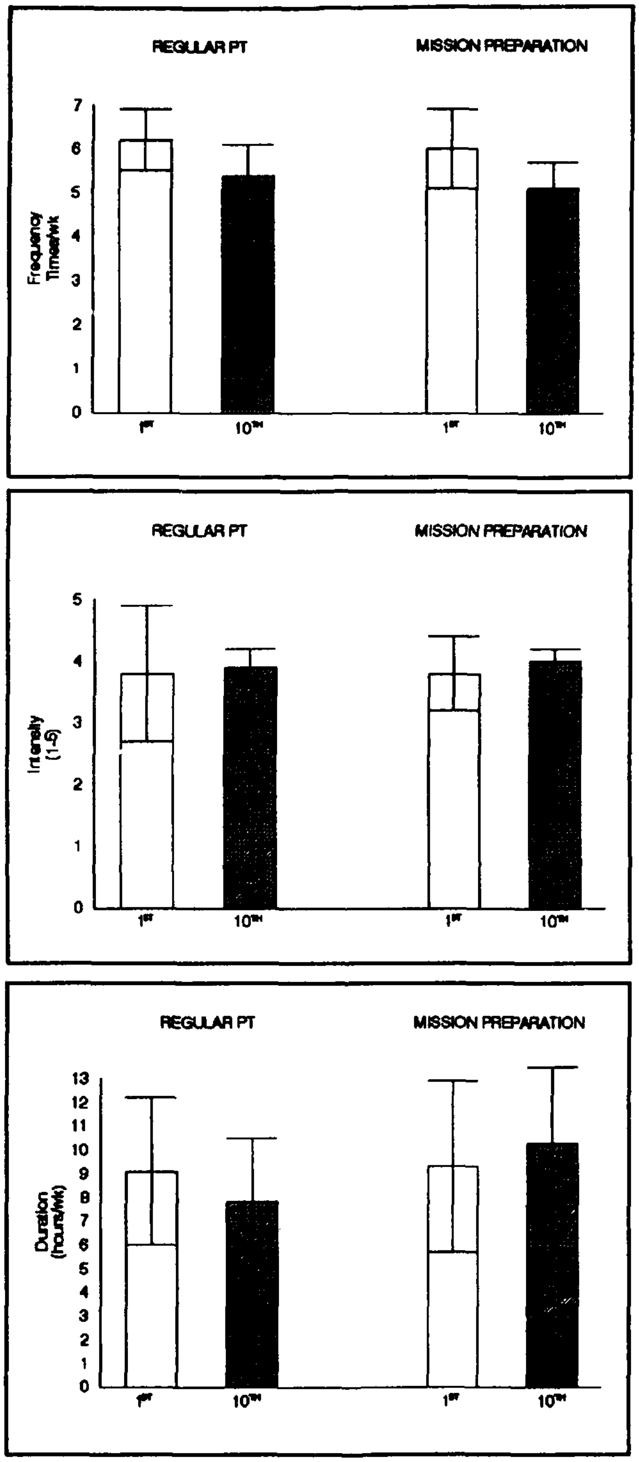

FIG 3. Habitual physical activity of 2 teams of SOF soldiers. Frequency (times/week), intensity (1=very easy, 2=easy, 3=moderate, 4=hard, 5=very hard), duration (hours/week) of physical activity during regular PT and mission preparation in 19 SOF soldiers. Open bars: 1st SFG, Ft.Lewis WA; hatched bars: 10th SFG, Ft. Devens, MA.

Metabolic Variation

In Study 1 (27), the amount of carbohydrate utilized as substrate during exercise calculated from respiratory data (24) was lower in all three conditions at SL than at HA at the same relative intensities (Table 5). This observation is consistent with published data (57). The coefficient of variation within groups indicates the amount of variation among individual samples and represents inter-individual variation. The coefficients of variation for grams of carbohydrate utilized during exercise ranged from 13.5% during the HA treadmill exercise for 1 hour at 75% $\dot{V}o_2max$ to 26.8% during the 4 hours at 50% $\dot{V}o_2max$ at HA. This variation may represent differences in metabolism, although there are several factors in addition to metabolic differences which may contribute to this wide variation: the diets and physical activity of the volunteers were not strictly controlled and the small number of volunteers who completed each experimental condition, 3 or 4, was not adequate to calculate a representative population variance.

TABLE 5. Grams of carbohydrate utilized for energy production during exercise at sea level (SL, 50m) and high altitude (HA, 4300 m) during Study 1 (27).

Subject No.	g CHO·min^{-1} 50%$\dot{V}O_2$max (1 hour) SL	Subj. No.	g CHO·min^{-1} 50%$\dot{V}O_2$max (4 hours) SL	Subj. No.	g CHO·min^{-1} 75%$\dot{V}O_2$max (1 hour) SL
02	0.68	02	1.04	10	3.69
03	1.08	03	1.11	13	3.26
05	1.21	05	1.36	14	3.07
08	1.06	08	1.40	15	2.39
$\bar{X}$±s	1.01 ± 0.23		1.23 ± 0.18		3.10 ± 0.54
cv	22.8%		14.6%		17.4%

Subject No.	g CHO·min^{-1} 50%$\dot{V}O_2$max (1 hour) HA	Subj. No.	g CHO·min^{-1} 50%$\dot{V}O_2$max (4 hours) HA	Subj. No.	g CHO·min^{-1} 75%$\dot{V}O_2$max (1 hour) HA
03	0.43	03	0.50	10	2.25
05	0.32	05	0.29	13	1.68
08	0.50	08	0.45	14	2.29
				15	2.08
$\bar{X}$±s	0.42 ± 0.09		0.41 ± 0.11		2.08 ± 0.28
cv	21.4%		26.8%		13.5%

$\bar{X}$, mean
s, standard deviation
cv, coefficient of variation

During the prolonged treadmill exercise in Study 2, the blood metabolites, triglycerides, free fatty acids, beta hydroxybutyrate, and glycerol demonstrated response patterns consistent with previously reported data (16, 20, 28). Variation during exercise (Pre, 10 min, 20 min, 40 min, and 60 min) ranged from 12.1% to 66.1% with a mean coefficient of variation during exercise of 38.1% (Appendix C). As in Study 1, there are several variables in addition to metabolic variation which may contribute to inter-individual variability in metabolite responses: diets and physical activity of the volunteers were not strictly controlled and the blood values were not corrected for changes in plasma volume. An examination of physiological response to exercise under more controlled conditions would provide the opportunity to evaluate discrete metabolic differences.

Nutrition During Deployment

Nutrient intakes were calculated by factoring individual food items reported against known macro- and micro-nutrient values. The nutrient factor file included nutrient composition values provided by Natick Research Development and Engineering Center (ration items) and the US Department of Agriculture Nutrient Data Base for Standard Reference (Handbook 8). Data reduction was done on a Digital Equipment Corporation Vax 780 computer using the Computerized Analysis of Nutrients (CAN) system developed by USARIEM (46). Nutrients reported include: energy (kcal), protein (Pro), carbohydrate (CHO), fat, sodium, thiamin, riboflavin, niacin, vitamin B6, iron, magnesium, zinc, calcium, phosphorus, ascorbic acid, folacin, and vitamin A. Mean nutrient intakes were compared to the Military Recommended Dietary Allowances (MRDA) found in AR 40-25 (Dept of Army).

Mean nutrient intakes compared to MRDA requirements are presented in Table 6. Although the self-reported energy intake of these SOF soldiers may seem low, the data are comparable to other USARIEM field study findings (34). Past field trials reveal that there is an intake ceiling equal to approximately 3000 $kcal \cdot day^{-1}$ and 300 g $CHO \cdot day^{-1}$. Adequate protein intake does not appear to be a problem with these soldiers or in past field studies.

On average, these soldiers consumed 70 to over 100% of the MRDA for all micro-nutrients listed, with the exception of folacin and vitamin E. Since the vitamin and mineral content of ration components are often unevenly distributed among food items, care must be taken when the entire ration allotment is not consumed.

TABLE 6. Daily Nutritional Intake and Military Recommended Dietary Allowances[1]

Nutrient	Unit	Reported	MRDA	%MRDA
Energy	kcal	2419±918	3600	67
Protein	g	92±27	100	92
CHO	g	302±155	-	-
Fat	g	96±32	-	-
Sodium	mg	4557±1484	5500	83
Thiamin	mg	3.8±2.5	1.6	238
Riboflavin	mg	1.8±0.7	1.9	95
Niacin	mg NE	28±9	21	133
Vitamin B6	mg	2.4±1.6	2.2	109
Iron	mg	16±8	10-18	114
Magnesium	mg	343±180	350	98
Zinc	mg	11±16	15	73
Calcium	mg	763±395	800	95
Phosphorus	mg	1330±571	800	166
Ascorbic acid	mg	100±77	60	167
Folacin	mcg	219±133	400	55
Vitamin A	mcg RE	1235±1623	1000	124
Vitamin E	mcg TE	6.8±3.6	10	68

[1]Mean ± s

CONCLUSIONS

1. Using anthropometric data (height, weight, percent body fat, and lean body mass) and $\dot{V}o_2max$ as criteria, SOF soldiers are a statistically distinct sub-group within the U.S. Army. The greater mean lean body mass and mean $\dot{V}o_2max$ indicate that the SOF soldier has a greater performance capacity than the non-SOF U.S. Army soldier.

2. The SOF soldiers surveyed for this evaluation were highly active (304.3 $kcal \cdot kgBW^{-1} \cdot wk^{-1}$ or ≈ 3500 $kcal \cdot da^{-1}$). Occupational and recreational physical activities of SOF soldiers are diverse. This pattern of diversity mimics the cross-training recommended to athletes. It encourages the development of many different muscle groups which enhances efficiency in physical performance and is somewhat protective against injury. Physical activity during missions is highly variable, reflecting the varied demands of different types of missions.

3. Metabolic response during exercise demonstrated considerable variation between individuals, as indicated by the coefficient of variation within groups. Examination of metabolic response to exercise under more controlled conditions would provide the opportunity to evaluate discrete metabolic differences.

4. The results of the nutrition survey are in concert with previous research which indicates that soldiers in the field do not consume more than 3000 $kcal \cdot da^{-1}$ and that carbohydrate intake approximates 300 $gram \cdot da^{-1}$, which is below the 400 $gram \cdot day^{-1}$ recommended by the Committee on Military Nutrition. Under conditions of strenuous daily physical activity, this total intake is calorically inadequate, leading to a negative energy balance. Additionally, inadequte carbohydrate intake will prevent the restoration of glycogen stores leading to decrements in physical performance.

REFERENCES

1. Ahlborg, B., Bergstrom J., Ekelund, L.G., and Hultman, E. Muscle glycogen and muscle electrolytes during prolonged physical exercise. Acta Physiol Scand, 70: 129-142, 1967.

2. Astrand, P.O. and Rodahl, K. Nutrition and physical performance, In: Textbook of Work Physiology. 3rd Edition McGraw-Hill Book Co., New York, 523-576, 1986.

3. Baecke, J.A.H., Burema, J., and Frijters, J.E.R. A short questionnaire for the measurement of habitual physical activity in epidemiological studies. Am J Clin Nutr, 36: 936-942, 1982.

4. Bergstrom, J. and Hultman, E. Muscle glycogen synthesis after exercise: an enhancing factor localized to the muscle cells in man. Nature, 210: 309-310, 1967.

5. Bergstrom, J., Hermansen, L., Hultman, E., and Saltin, B. Diet, muscle glycogen and physical performance. Acta Physiol Scand, 71: 140-150, 1967.

6. Borg, G., and Linderholm, H. Perceived exertion and pulse rate during graded exercise in various age groups. Acta Med Scand Suppl, 472:194-206, 1967.

7. Bouchard, C. Genetics of Aerobic Power and Capacity, In: Sport and Human Genetics. Human Kinetics Publ., Champaign, Illinois, 59-88, 1986.

8. Bouchard, C., Chagnon, M., Thibault, M.C., et al. Muscle genetic variants and relationship with performance and trainabiity. Med Sci Sports Exerc, 21: 71-77, 1989.

9. Brooks, G.A. Amino acid and protein metabolism during exercise and recovery. Med Sci Sports Exerc, 19(5): S150-56, 1987.

10. Christensen, E.H., and Hansen, O. Arbeitsfahigkeit und Ehrnahrung. Scand Arch Physiol, 81: 160, 1939.

11. Coyle, E.F., Hagberg, J.M., Hurley, B.F., Martin, W.H., Ehsani, A.A. and Holloszy, J.O. Carbohydrate feeding during prolonged strenuous exercise can delay fatigue. J Appl Physiol: Respirat Environ Exercise Physiol, 55: 230-235, 1983.

12. Coyle, E.F., Coggan, A.R., Hemmert, M.K., and Ivy, J.L. Muscle glycogen utilization during prolonged strenuous exercise when fed carbohydrate. J Appl Physiol, 61: 165-172, 1986.

13. Cunningham, J.J. A reanalysis of the factors influencing the basal metabolic rate in normal adults. Am J Clin Nutr, 33: 2372-2374, 1980.

14. Cunningham, J.J. Body composition as a determinant of energy expenditure: a synthetic review and a proposed general prediction equation. Am J Clin Nutr, 54: 963-969, 1991.

15. Cymerman, A., Hoyt, R.W., Muza, S.R., et al. Pikes Peak 1992: Physiological responses during and following acclimatization to high altitude. USARIEM Protocol APMD92003-AP016-H018, August 3, 1992.

16. Décombaz, J., Arnaud, M.J., Milon, H., et al. Energy metabolism of medium-chain triglycerides versus carbohydrates during exercise. Eur J Appl Physiol, 52: 9-14, 1983.

17. Departments of the Army, the Navy, and the Air Force. Army Regulation 40-25, Naval Command Instruction 10110.1, and Air Force Regulation 160-95 Nutrition, Allowances, Standards and Education. Washington D.C., Headquarters Department of the Army, the Navy, and the Air Force, Washington D.C., 15 May 1985.

18. Dishman, R.K. and Steinhardt, M. Reliability and concurrent validity for a 7-day re-call of physical activity in college students. Med Sci Sports and Exerc , 20(1): 14-25, 1988.

19. DuBois, D. and DuBois, E.F. Clinical Calorimetry. A formula to estimate the approximate surface area if height and weight be known. Arch Intern Med, 17: 863-871, 1916.

20. Eaton, P. and Steinberg, D. Effects of medium fatty acid concentration, epinephrine, and glucose on palmitate-1-C^{14} oxidation and incorporation into neutral lipids by skeletal muscle in vivo. J Lipid Res, 2: 376-382, 1961.

21. Edwards, H.T., Margaria, R., and Dill D.B. Metabolic rate, blood sugar and the utilization of carbohydrate. Am J Physiol, 108: 203-209, 1934.

22. Galbo, H., Holst, J.J., and Christensen, N.J. The effect of different diets and of insulin on the hormonal response to prolonged exercise. Acta Physiol Scand, 107: 19-32, 1979.

23. Galbo, H. Adrenocorticotropic hormone (ACTH) and adrenal glucocorticoids, In: Hormonal and Metabolic Adaption to Exercise. Thieme-Stratton, Inc., New York, 46-51, 1983.

24. Gollnick, P.D. Energy production during exercise, In: Military Nutrition Research Annual Report. October 1, 1986-September 30, 1987, pp. 28-46.

25. Hargreaves, M., Costill, D.L., Coggan, A., Fink, W.J., and Nishibata, I. Effect of carbohydrate feedings on muscle glycogen utilization and exercise performance. Med Sci Sports Exerc, 16: 219-222, 1984.

26. Herman, R.H., Zakim, D., and Stifel, F.B. Effect of diet on lipid metabolism in experimental animals and man. Fed Proc, 29(3): 1302-1307, 1970.

27. Hoyt, R.W., Fulco, C., Iwanyk, E., et al. Effects of carbohydrate intake on water and energy metabolism of soldiers exposed to 4300 m. USARIEM Protocol May 1989.

28. Hoyt, R.W., Jones, T.E., Rose, M.S., et al. Dietary fat does not affect fuel oxidation or endurance exercise performance of soldiers. Natick, MA: U.S. Army Research Institute of Environmental Medicine, Technical Report T5-91, 1991.

29. Ivy, J.L., Costill, D.L., Fink W.J., and Maglischo, E. Contribution of medium and long chain triglyceride intake to energy metabolism during prolonged exercise. Int J Sports Medicine, 1: 15-20, 1980.

30. Ivy, J.L., Frishberg, B.A., Farrell, S.W., Miller, W.J., and Sherman, W.M. Effects of elevated and exercise-reduced muscle glycogen levels on insulin sensitivity. J Appl Physiol, 59(1): 154-159, 1985.

31. Ivy, J.L., Lee, M.C., Brozinick, J.T., and Reed, M.J. Muscle glycogen storage after different amounts of carbohydrate ingestion. J Appl Physiol, 65: 2018-2023, 1988.

32. Ivy, J.L., Katz, A.L., Cutler, C.L., Sherman, W.M., and Coyle, E.F. Muscle glycogen synthesis after exercise: effect of time of carbohydrate ingestion. J Appl Physiol, 64(4): 1480-1485, 1988.

33. Jacobs, I., Prusaczyk, W.K., and Goforth, H.W. Muscle glycogen, fiber type, aerobic fitness, and anaerobic capacity of west coast U.S. Navy Sea-Air-Land personnel (SEALS). San Diego, CA: Naval Health Research Center, Technical Report 92-10, 1992.

34. Jones, T.E., Hoyt, R.W., Baker, C.J., et al. Voluntary consumption of a liquid carbohydrate supplement by Special Operations Forces during a high altitude cold weather field training exercise. Natick, MA: U.S. Army Research Institute of Environmental Medicine, Technical Report T20-90, 1990.

35. Kahn, C.R., Smith, R.J., and Chin W.W. Mechanism of action of hormones that act at the cell surface, In: Williams Textbook of Endocrinology, 8th Edition. J.D. Wilson and D.W. Foster (Eds.) W.B. Saunders Company, Philadelphia, 91-134, 1992.

36. Lemon, P.W.R. and Nagle, F.J. Effects of exercise on protein and amino acid metabolism. Med Sci Sports Exerc, 13(3): 141-49, 1981.

37. Lemon, P.W.R., and Mullin, J.P. Effect of initial muscle glycogen levels on protein catabolism during exercise. J Appl Physiol: Respirat Environ Exercise Physiol, 48: 624-629, 1980.

38. Maughan, R.J., Williams, C., Campbell, D.M., and Hepburn, D. Fat and carbohydrate metabolism during low intensity exercise: effects of the availability of muscle glycogen. Eur J Appl Physiol, 39: 7-16, 1978.

39. McArdle, W.D., Katch, F.I., and Katch V.L. Human energy expenditure during rest and physical activity, In: Exercise Physiology: Energy, Nutrition, and Human Performance. Lea & Febiger, Philadelphia, 158-173, 1991.

40. McArdle, W.D., Katch, F.I., Katch V.L. Body Composition Assesment, In: Exercise Physiology: Energy, Nutrition, and Human Performance. Lea & Febiger, Philadelphia, 599-633, 1991.

41. Military Nutrition Research Annual Report October 1, 1986 - September 30, 1987. Workshop on calorie-dense rations. National Academy Press, Washington, D.C.,1988.

42. Muza, S.R., Sawka, M.N., Young, A.J., et al. Elite Special Forces: physiological description and ergogenic influence of blood reinfusion. Aviat Space Environ Med, 58:1001-4, 1987.

43. Newsholme, E.A. Carbohydrate metabolism in vivo: regulation of the blood glucose level. Clin Endocrinol Metab, 5: 543-578, 1976.

44. Randle, P.J., Garland, P.B., Hales, C.N., and Newsholme, E.A. The glucose fatty acid cycle. Its role in insulin sensitivity and the metabolic disturbances of diabetes mellitus. The Lancet, 34: 785-789, 1963.

45. Ravussin, E., and Bogardus, C. Relationship of genetics, age, and physical fitness to daily energy expenditure and fuel utilization. Am J Clin Nutr, 49: 968-975, 1989.

46. Rennie, M.J. and Holloszy, J.O. Inhibition of glucose uptake and glycogenolysis by availability of oleate in well-oxygenated and perfused skeletal muscle. Biochem J, 168: 161-170, 1977.

47. Rose, M.S., Finn, J., Radovsky, C., et al. Computerized Analysis of Nutrients (CAN) System. Natick, MA: U.S. Army Research Institute of Environmental Medicine, Technical Report TR-2-90, November 1989 (DTIC No. AD-A221 429).

48. Sargent, F., Sargent, V.W., Johnson, R.E., and Stolpe, S.G. The physiological basis for various constituents in survival rations. I The efficiency of young men under temperate conditions. Ohio: Wright-Patterson Air Force Base, Technical Report 53-484, 1954.

49. Sargent, F. II, Sargent, R.E. Johnson, and S.G. Stolpe. The physiological basis for various constituents in survival rations. II. The efficiency of young men under conditions of moderate cold. Ohio: Wright-Patterson Air Force Base, Technical Report 53-484, part 2, vols. I and II, 1955.

50. Sargent, F. II, V.W. Sargent, and R.E. Johnson. The physiological basis for various constituents in survival rations. III. The efficiency of young men under conditions of moist heat. Ohio: Wright-Patterson Air Force Base, Technical Report 53-484, part 3, vols. I and II, 1957; 1958.

51. Tremblay, A., Poehlman, E., Nadeau, A., Perusse, L., and Bouchard, C. Is the response of plasma glucose and insulin to short-term exercise training genetically determined? Horm Metab Res, 19: 65-67, 1987.

52. Umbarger, H.E. and Zubay, G. Catabolism of amino acids, In: Biochemistry. G. Zubay (Coordinating Author) Macmillan Publishing Company, New York, 615-644, 1988.

53. Viru, A. Hormonal ensemble in exercise, In: Hormones in Muscular Activity. CRC Press, Inc., Boca Raton, FL, 127-131, 1985.

54. Viru, A., Karelson, K. and Smirnova, T. Stability and variability in hormonal responses to prolonged exercise. Int J Sports Med, 13(3): 230-235, 1992.

55. Vogel, J.A., Patton, J.F., Mello, R.P. and Daniels, W.L. An analysis of aerobic capacity in a large United States population. J Appl Physiol, 60(2): 494-500, 1986.

55. Young, D.R., Pelligra, R. and Adachi, R.R. Serum glucose and free fatty acids in man during prolonged exercise. J Appl Physiol, 21: 1047-1052, 1966.

56. Young, A.J., Evans, W.J., Cymerman, A., Pandolf, K.B., Knapik, J.J. and Maher, J.T. Sparing effect of chronic high-altitude exposure on muscle glycogen utilization. J Appl Physiol: Respirat Environ Exercise Physiol, 52(4): 857-862, 1982.

APPENDIX A
TECHNOLOGY BASE PROJECT DEFINITION DOCUMENT

SOF TECHNOLOGY BASE PROJECT DEFINITION DOCUMENT

FOR

SPECIAL OPERATIONAL FORCES (SOF)

INDIVIDUAL OPERATIONAL RATION

Project No. 92-TA-4

Director, SORDAC

James A Gust
J3, USSOCOM

Sponsoring Component
JAMES ROBERTSON
Chief, Force Integration Division

LABORATORY
ROBERT W. LEWIS
Technical Director
U.S. Army Natick Research, Development
and Engineering Center

GARY L. WEBER
COL, SF
Director, Combat Developments
U.S. Army John F. Kennedy Special
Warfare Center and School

SPECIAL OPERATIONS RESEARCH, DEVELOPMENT,
AND ACQUISITION CENTER

UNITED STATES SPECIAL OPERATIONS COMMAND

MACDILL AIR FORCE BASE, FL 33608-6001

OPERATIONAL FORCES (SOF)
INDIVIDUAL OPERATIONAL RATION

1. DEFENSE PLANNING GUIDANCE ELEMENT. The program objective is to provide a customized, lightweight, and nutritionally balanced, packaged food source for sustainment of the SOF soldier as part of the Draft Special Operations Forces (SOF) Annex to the Soldier Moderization Plan (SMP).

2. REFERENCES. ~~Missions Needs Statement~~ for Individual Operational Rations, U.S. Army John F. Kennedy Special Warfare Center and School (USAJFKSWCS), Fort Bragg, NC, 16 Aug 91.

3. THREAT/TARGETS. Current field rations are heavy, bulky, and require excessive amounts of water to reconstitute and are not, by themselves, nutritionally balanced or mission designed. The potential for Low Intensity Conflict/limited war in any theatre worldwide and the resulting force projection requires that combat systems, to include rations, be capable of effective and sustained operations in desert, jungle, arctic, mountainous, and urban environments. The most technologically advanced threat to the SOF soldier occurs during the conduct of war, however, an ever increasing threat occurs throughout the operational continuum. Currently, all rations, with the exception of rations needed for three to five days (at one meal per day), inserted into the operational area must be cached, requiring SOF personnel to return periodically for resupply. The use of caching for outsized or heavy equipment is inevitable; however, the unnecessary exposure to retrieve rations adds risks to the operation and provides the enemy with a possibility to compromise, capture, or ambush SOF personnel.

4. DESIRED FUTURE CAPABILITY. This program will provide the SOF a packaged, compact, and nutritionally optimized ration system for the individual soldier that will provide readily utilizable food energy and bio-nutrients to enhance physical and mental performance. The individual ration system will be designed for compatibility with the load bearing equipment, be nutritionally dense, and tailored to meet the needs of the individual operating in various tactical and climatic environments. Nutritional density of the individualized rations will be maximized with respect to the operational scenario to reduce the total logistical burden of the soldier.

a. Description of Technology. Ration components and ingredients will be developed or adapted to exploit the beneficial aspect of certain micro- and macro-nutrients on human alertness, stress resistance, enhanced physical performance, mental acuity, and energy utilization. System studies will define the types of

operational scenarios that the ration must satisfy, i.e., level of activity, type of activity, length of mission, climatic condition, and stress factors. Computer software and/or artificial intelligence capabilities will be developed for simulating and evaluating modular design concepts for a customized ration. Enhanced performance, customer satisfaction, and logistical supportability will be incorporated as algorithmic goals of the computer model. Design parameters such as menu, weight, volume, nutrient content, and sustainability will be incorporated into the model. Software development will be tailored to assure a sufficient level of simplicity to allow use by professionals and nonprofessionals with limited computer skills. Proposed ration configuration performance will be tested through simulations to determine appropriateness to the various operational scenarios. System configuration design conflicts or the inability of the ration system to resolve requirements will be identified prior to full system development. Development of new packaging designs will be accomplished along with assembly technologies. The number and type of ration components will be maximized to assure menu variety, acceptance of the ration and manufacturing producibility. The feasibility of conducting individual metabolic stress testing for each SOF soldier and using the results in an computerized individual program to determine the dietary requirements for specific missions for that individual will also be addressed. The stress testing will be based on SOF mission scenarios with carriage (individual SOF soldier) loads in increments from 45 pounds to +100 pounds, in climatic conditions including hot/dry, hot/wet, cold/dry, cold/wet, and temperate. Temperature ranges will include -40 degrees to +120 degrees Fahrenheit. Environments will include desert, jungle, mountainous, and urban terrain. The stress testing and a pre-determined anxiety quotient will result in an individual data base that will recommend to the soldier and his commander the daily nutritional needs for sustainment on a specific mission and will be used by the soldier when planning a mission. The program product will be the development of a modular ration containing separate nutritional packets which can be reconfigured to supply specific daily nutritional needs based on each day's activity.

b. Background. The U.S. Army Natick Research, Development and Engineering Center (NRDEC) developed, tested and fielded the Ration, Lightweight-30 Days (RLW-30) against an operational requirement for a lightweight, calorie dense ration that can sustain the SOF soldier in clandestine operations up to 30 days without resupply. Existing subsistence items/rations that were available were too bulky or heavy, denying space needed for mission essential equipment. The RLW-30 is a pre-assembled, restricted ration packaged in a CB-proof, modular packet that can be eaten as is or with minimum preparation and a limited water supply. The desired ration characteristics were set by the SOF and the Office of The Surgeon General (OTSG). The ration weighs no more than one pound

(454 grams) per day and is no more than 45 cubic inches (737cc) in volume per day. The RLW-30 contains 2200 calories and is fortified to meet the OTSG and AR 40-25 requirements for a restricted ration. The RLW-30 has a six day menu cycle with a separate accessory packet for every six days. Thirty ration packets and five accessory packets are modularized into a compact package suitable for aero-delivery or normal supply channels. This ration is currently being procured by the Defense Personnel Support Center (DPSC). The U.S. Army Quartermaster Center and School (QMC&S) has also identified a need for an extended life operational ration that will be the primary assault/patrol and Prepositioned War Reserve Stocks (PWRS) ration. This extended life ration will be used during the initial ten days of conflict. The extended life capability of this ration will resolve current deficiencies noted in the Army's ability to rotate existing PWRS rations in a timely and cost effective manner. This ration, the Long Life Ration Packet (LLRP), takes advantage of current state of the art in production technology by drawing components, primarily freeze dehydrated and snack items, from existing military ration items. Demonstrated producibility and acceptance of these components from the Food Packet, Long-Range Patrol, the Food Packet Assault, and the Ration, Cold Weather offer a beneficial edge in fielding this LLRP for assault feeding. As a result, the LLRP possesses a proven high troop acceptance, it is inexpensive, has a ten year shelf life, satisfies the Minimum Recommended Daily Allowance for restricted rations (1500 kcal/day), weighs less than one pound per individual meal, reduces the logistical burden of maintaining PWRS, allows a reduction in long term storage requirements for Meal, Ready-to-Eat (MRE) resulting in fresher, higher quality food for the soldier and contains a dehydrated entree, a cereal bar, a cookie component, a candy component, and instant beverage. Natick is also currently developing the Modular Assault Ration (MAR): The MAR is one member of the family of Joint Operational Rations System responding to the need for a scenario-driven ration suitable for various assault tactical situations and climatic conditions. The MAR will be optimally mixed with other rations to simplify the management of PWRS. The MAR, responding to the needs of the integrated, non-linear, highly mobile, dispersed nature of the future battlefield, will be a more advanced, "eat-on-the-move" modular ration that exploits the latest advances in food technology. It will utilize commercial items where possible to ensure high soldier acceptability and a viable base for wartime surge production.

c. Concept. This ration system will consist of an individually nutritionally tailored, nutrient dense, ready-to-eat, ration packet for use by the SOF. This system will include consumable foodstuffs and specific computer software to permit individual tailoring. The foodstuff will not require special logistic support, and will use existing transportation, storage, and issue

techniques and facilities currently used for the MRE field rations. The software will be transported and safeguarded using existing established procedures. As in the MRE and RLW-30, the outer wrapper will provide the ration with chemical and biological protection. The ration will be an individual and mission-specific sustenance and will not require standardization and interoperability within the North Atlantic Treaty Organization and other allies. Special Operational Forces require a nutritionally balanced, lightweight, individually packed, mission specific ration ~~in order to~~ conduct unconventional warfare, special reconnaissance, counter narcotics, direct action, and other missions as assigned. The ration design will be such that producibility and commercial production base will not be a constraint.

5. PRIORITY. The Individual Operational Ration effort supports the SOF Annex to the U.S. Army's Soldier Modernization Plan (Draft 4QTR 91, Final 1QTR 92), SOF modernization for soldier enhancement, sustainment and survivability, and will be incorporated into the U.S. Special Operations Command (USSOCOM) Sustainment and Survivability Master Plan.

6. SCIENCE AND TECHNOLOGY OBJECTIVES.

a. Development Effort Scope. This effort will demonstrate the effectiveness of nutritionally tailoring a ration system for the specific needs of an individual SOF soldier operating under various operational and environmental conditions. Individualized nutritional profiles under stress and environmental conditions will be determined and computerized to allow tailoring of individually specific rations. The development effort will include computer modeling of modular ration concepts, individual testing to determine individual performance levels and needs, development or adaptation of ration components, development of formulation and processing techniques to incorporate and ensure delivery of performance enhancing ingredients, prototyping of advanced packaging systems, nutritional analysis of food items, consumer testing, and performance testing under field conditions. Logistical issues will be addressed as to the assembly and issue of the individualized rations. All Natick efforts will be conducted jointly and coordinated with the OTSG - U.S. Army Research Institute of Environmental Medicine (ARIEM). NOTE: This project shall not develop new ration components or ingredients without express approval of USSOCOM.

b. Technical Objective and Milestones. The program is a four year program divided into the following phases:

FY92

(1) Develop and test computer model for modular ration design evaluation and optimization.

(2) Initiate studies to determine nutritional needs [illegible] mission requirements.

(3) Conduct studies to determine nutritional profile requirements of individual soldiers under stress conditions and in [illegible] cold, and temperate environments.

(4) Initiate sensory and behavioral research studies to identify soldier satisfaction with ration concept including an assessment of the behavioral impact of the specialization of nutritional profile for individual soldiers.

FY93

(1) Continue individual testing for determining nutritional requirement profiles. Testing by OTSG - ARIEM will include weight loss, food intake, and metabolic parameters such as urine, blood, and respiration.

(2) Program will be designed to store, eval- uate, and manipulate individual profiles and design individualized diets.

(3) Conduct chamber tests with different environments to determine individual changes in nutrient requirements.

(4) Develop strategies for promoting consumption of familiar foods.

(5) Study effect of ration consumption on water intake.

(6) Demonstrate acceptance of ration components. Quantitative approaches to sensory psychophysics and acceptance optimization will be used to generate component/item profiles, assess critical factors contributing to item acceptance and to optimize user satisfaction.

(7) Conduct joint working group meeting for decision on ration design and establish field test criteria.

(8) Initiate contract action for procurement of prototypes for field testing.

FY94

(1) Support research and development production test for production of assembled rations.

(2) Conduct extensive field testing using SOF personnel to determine acceptance of the ration in terms of sensory and performance data.

(3) Refine ration design based on results of field testing.

(4) Complete technical data packages for ration components and packaging systems.

(5) Prepare final reports.

(a) Ration Technology.

(b) Field Testing.

(6) Conduct joint working group meeting for acceptance of ration system.

FY95. Transition to SOF.

c. Technology Issues or Barriers. There are no pacing technical barriers that would affect successful completion of this effort. The determination of the existence of sufficient metabolic differences between individuals to warrant dietary customization is a key issue to be addressed. Further, the identification of performance enhancing ingredients and the formulation and processing techniques necessary to incorporate them in the ration and ensure their delivery through the digestive process is another big technical challenge. Expertise in the food and packaging technologies are available at Natick, nutritionists and physiologists are available at ARIEM, and individuals proficient in computer modeling and data base entry will be utilized. A critical issue will be availability of test troops from SOF units. Without ready access to these test troops, the completion milestone of FY95 transition will not be met.

7. SPECIFIC PROJECT TASKS.

a. Component optimization of Specialized Individual Ration System Lead: Technology Acquisition Division (TAD), Food Engineering Directorate (FED), and Food Technology Division (FTD), FED.

b. Development/Adaptation of Ration Items. Lead: Product Development and Engineering Branch (PD&EB), FTD, FED, NRDEC.

c. Packaging and Assembly Design. Lead: Subsistence Production Branch, FTD, FED.

d. Nutritional Analysis of Component Items. Lead: TAD, FED.

e. Acceptance and Behavioral Engineering of Individualized Ration. Lead: Behavior Science Division (BSD), Soldier Science Directorate (SSD).

f. Nutritional Profiling of Individual Soldiers. Lead: Military Nutrition Division (MND), ARIEM.

g. Field Evaluation of Individual Operational Ration. Lead: MND, ARIEM and BSD, SSD.

h. Acquisition Management and Document Preparation. Lead: FTD, FED.

8. PROJECT MANAGEMENT RESPONSIBILITIES.

a. The Special Operations Research, Development, and Acquisition Center (SORDAC) assist in assuring that the program conforms to SOF soldier requirements.

b. The NRDEC manage and conduct the program. The project management for the Individual Operational Ration will be under the direction of FTD, FED. Ms. Vicki Loveridge, Senior Food Technologist, will serve as project officer for the ration development, prototyping, and production testing of the rations. The In-Process-Review (IPR) and joint working group chairman will be Mr. Gerald Darsch, Chief, FTD, FED. This ration is a special purpose, low intensity use item for SOF only and does not require type classification.

c. The U.S. Army Institute of Environmental Medicine. LTC Wayne Askew, Chief, MND, ARIEM will be responsible for all nutritional profiling and field testing (including troop requests), coordination of all medical and behavioral test criteria, and outline test plans.

d. The U.S. Army John F. Kennedy Special Warfare Center and School, Directorate of Combat Developments (DCD, USAJFKSWCS). Combat Developer. Will be responsible for providing soldiers and evaluators for field evaluations. Assist in assuring that the program conforms to SOF soldier operational requirements.

9. MILESTONES AND DELIVERABLES.

	FY92				FY93				FY94				FY95
	1	2	3	4	1	2	3	4	1	2	3	4	1QTR
Concept Requirement	X												
Analysis of Nutritional Need versus Mission	XXXXXXXXXX												
Initiate Component Development and Testing	XXXXXXXXXXXXXXXXXXXXX												
Individual Testing for Nutritional Requirements			XXXXXXXXXXXX										
Develop Computer program for Individual Nutritional profiles					XXXXXXXXXX								
Prototype Modular Nutrient Specific Ration								X					
Conduct Joint Working Group								X					
Contract for Prototype Ration								XXXXXXX					
Initiate Field Testing Arctic/Desert/Temperate								XXXXXXXXXXXXXXXX					
Refine Modular Ration												X	
Conduct IPR												X	
Transition to SOP													X

10. TECHNOLOGY TRANSFER CONCEPT. At the completion of this study, Technical Data Packages (TDP) will be finalized and available for procurement use by SOF. The TDP will include both ration components and packaging systems.

11. RESOURCES.

P.E. Number	Type Funds	Prior	FY92	FY93	FY94
	PF-II				
1160401BB	6.2/6.3A	None	$300K	$300K	$350K

12. REVIEW PROCESS. An initial meeting with all program members will be held at USSOCOM. The program progress will be mentioned through joint working group meetings and quarterly reports submitted to SORDAC, USSOCOM, and DCD, USAJFKSWCS. Committee members will include USAJFKSWCS, SORDAC, NRDEC, DPSC, QMC&S, and OTSG. Decisions will be voted upon with NRDEC, ARIEM, SORDAC, USAJFKSWCS, and OTSG having one vote each. A joint working group will be conducted prior to initiation of field testing and upon completion of all test and evaluation programs.

13. PROJECT MANAGEMENT POCs.

a. SORDAC:

(1) PM-SOF TECH BASE: MS Deanna J. Bennett

(2) Transition Systems Manager: COL Marcus L. Sherrill, USOCOM,SOSD

b. Sponsor/User(s):

(1) Component(s), DCD, USAJFKSWCS: COL Gary L. Weber

(2) USSOCOM Staff Sponsor: SOJ4

(3) J3-R, USSOCOM:

c. Developers:

(1) Project Manager: NRDEC, Ms. Loveridge, PD&EB, FTD, FED STRNC-WTP 508-651-5035, DSN 256-5037, FAX# 256-5274.

(2) Project Manager: ARIEM, LTC Wayne Askew Chief, MND SGRD-UE-NR 508-651-4874, DSN 256-4874, FAX# 256-5298.

APPENDIX B
PHYSICAL ACTIVITY DATA

TABLE B.1. Summary of the physical activity data in means, standard deviations, and coefficients of variation by team and activity category.

	FORT LEWIS TEAM			FORT DEVENS TEAM		
REGULAR PT:						
	frequency	intensity	duration	frequency	intensity	duration
$\bar{X}$±s	6.2±0.7	3.8±1.1	9.1±3.1	5.4±0.7	3.9±0.3	7.8±2.7
cv	11.3%	28.9%	34.1%	13.0%	7.7%	34.6%
MISSION PREPARATION:						
	frequency	intensity	duration	frequency	intensity	duration
$\bar{X}$±s	6.0±0.9	3.8±0.6	9.3±3.6	5.1±0.6	4.0±0.2	10.3±3.2
cv	15.0%	15.8%	38.7%	11.8%	5.0%	31.1%
INFILTRATION:						
	frequency	intensity	duration	frequency	intensity	duration
$\bar{X}$±s	2.3±1.6	4.0±0.5	11.0±3.8	2.5±1.6	3.9±0.3	11.1±3.9
cv	69.6%	12.5%	34.5%	64.0%	7.7%	35.1%
MISSION:						
	frequency	intensity	duration	frequency	intensity	duration
$\bar{X}$±s	8.3±5.5	3.0±0.8	40.8±21.5	6.3±3.1	2.7±0.9	26.2±14.5
cv	66.3%	26.7%	52.7%	49.2%	33.3%	55.3%
EXFILTRATION:						
	frequency	intensity	duration	frequency	intensity	duration
$\bar{X}$±s	1.5±0.6	3.7±0.6	16.7±14.7	1.5±0.9	3.7±0.4	14.5±6.1
cv	40.0%	16.2%	88.0%	60.0%	42.1%	10.8%

frequency, times per week; intensity, 1=very easy, 2=easy, 3=moderate, 4=hard, 5=very hard; duration, hours per week; $\bar{X}$, mean; s, standard deviation; cv, coefficient of variation

APPENDIX C
VARIATION IN METABOLIC DATA

TABLE C.1. Summary of variation in blood substrate and metabolite concentrations in samples from subjects exercising at sea level (15) and variation in assay controls (low and high).

	coefficient of variation			assay variance	
	low	high	mean	low	high
TRI	29.4%	38.4%	33.8%	1.6% ($100 mgm \cdot dL^{-1}$)	2.7% ($200 mgm \cdot dL^{-1}$)
FFA	24.7%	38.3%	31.6%	1.9% ($0.50 mM \cdot L^{-1}$)	7.4% ($2.0 mM \cdot L^{-1}$)
BOHB	35.6%	66.1%	48.5%	12.5% ($0.25 mM \cdot L^{-1}$)	5.8% ($1.0 mM \cdot L^{-1}$)
GLY	12.1%	37.5%	27.1%	9.1% ($0.10 mM \cdot L^{-1}$)	4.0% ($0.50 mM \cdot L^{-1}$)

TRI, triglycerides
FFA, free fatty acids
BOHB, β hydroxybutyrate
GLY, glycerol

APPENDIX D
PHYSICAL ACTIVITY QUESTIONNAIRE

PHYSICAL ACTIVITY QUESTIONNAIRE
INDIVIDUAL OPERATIONAL RATION PROJECT

The purpose of this questionnaire is to characterize your physical activity during regular PT, during preparation for a mission and during the mission itself. Please answer each question to the best of your ability.

1. Please characterize your regular PT by completing the following chart:

	WHAT TYPE OF EXERCISE (JOG, SPRINT, SWIM, LIFT WEIGHTS ETC.)?	HOW LONG DOES DOES THE EXERCISE SESSION LAST?	USING THE SCALE BELOW, PLEASE RATE THE INTENSITY OF EACH EXERCISE.
SUNDAY			
MONDAY			
TUESDAY			
WEDNESDAY			
THURSDAY			
FRIDAY			
SATURDAY			

1= VERY EASY: breathing easily, about the same as a slow walk.
2= EASY: breathing and effort slightly more than a slow walk
3= MODERATE: breathing definitely increased, but not uncomfortable
4= HARD: breathing hard, have to "push" to keep going, sweating
5= VERY HARD: breathing labored, very difficult to keep going, sweating heavily

2. Do you ever wear a rucksack during your regular PT? __________
If yes, how often ?________________________________

3. Do you participate in recreational sports? __________

a. If yes, please list the sports in which you participate on a regular basis. ________________

____

b. Is your participation seasonal or do you continue to participate throughout the year? ________________

____

Questions 4-7 refer to the changes in your physical training <u>prior to</u> the isolation phase of a mission.

4. Is your physical training prior to a mission specific to the physical requirements of that mission?__________

5. How long does this mission-specific phase of your training last (number of days)?__________

6. Do you wear a rucksack during your mission-specific training ? __________ If yes, how often? ________________

____

7. Please characterize your mission-specific <u>physical</u> training by completing the following chart. If your physical training differs from mission to mission, please describe your training prior to your last mission:

	WHAT TYPE OF EXERCISE (JOG, SPRINT, SWIM, LIFT WEIGHTS ETC.)?	HOW LONG DOES DOES THE EXERCISE SESSION LAST?	USING THE SCALE BELOW, PLEASE RATE THE INTENSITY OF EACH EXERCISE.
SUNDAY			
MONDAY			
TUESDAY			
WEDNESDAY			
THURSDAY			

FRIDAY			
SATURDAY			

1= VERY EASY: breathing easily, about the same as a slow walk.
2= EASY: breathing and effort slightly more than a slow walk
3= MODERATE: breathing definitely increased, but not uncomfortable
4= HARD: breathing hard, have to "push" to keep going, sweating
5= VERY HARD: breathing labored, very difficult to keep going, sweating heavily

Questions 8-11 refer to the infiltration/movement-to-the-objective phases of the mission.

8. How long (number of hours, days) do these phases of a mission typically last?__________

9. During these phases of a mission, how many hours of a day would you generally be physically active? __________

10. Is that activity continuous or sporadic? ____________________

    If the activity is sporadic,

    a. how long are the periods of activity ? __________

    b. How long are the intervening rest periods?

    ____

11. Using the scale below, please rate the intensity during periods of physical activity.__________

1= VERY EASY: breathing easily, about the same as a slow walk.
2= EASY: breathing and effort slightly more than a slow walk
3= MODERATE: breathing definitely increased, but not uncomfortable
4= HARD: breathing hard, have to "push" to keep going, sweating
5= VERY HARD: breathing labored, very difficult to keep going, sweating heavily

Questions 12-13 refer to the mission itself.

12. <u>Excluding</u> the infiltration/movement-to-the-objective and exfiltration phases, how long does a mission usually last (number of days, weeks)?________________________________

13. Please characterize your physical activity during a mission by completing the following chart:

	WHAT TYPE OF ACTIVITY (WALK, JOG, SPRINT, ETC.)?	HOW LONG DOES DOES THE PHYSICAL ACTIVITY LAST ?	USING THE SCALE BELOW, PLEASE RATE THE INTENSITY OF EACH EXERCISE
DAY 1			
DAY 2			
DAY 3			
DAY 4			
DAY 5			
DAY 6			
DAY 7			

1= VERY EASY: breathing easily, about the same as a slow walk.
2= EASY: breathing and effort slightly more than a slow walk
3= MODERATE: breathing definitely increased, but not uncomfortable
4= HARD: breathing hard, have to "push" to keep going, sweating
5= VERY HARD: breathing labored, very difficult to keep going, sweating heavily

The following four questions, 14-17, refer to the exfiltration phase of the mission.

14. How long does the exfiltration phase of the mission usually last (number of hours, days)?____________________

15. During this exfiltration phase of the mission, how many hours (per day) would you be required to be physically active ?

____

16. Is that activity continuous or sporadic? ___________
If the activity is sporadic,

a. how long are the periods of activity ? ___________

b. how long are the intervening rest periods?_________

____

17. Using the scale below, please rate the intensity during periods of physical activity._________

1= VERY EASY: breathing easily, about the same as a slow walk.
2= EASY: breathing and effort slightly more than a slow walk
3= MODERATE: breathing definitely increased, but not uncomfortable
4= HARD: breathing hard, have to "push" to keep going, sweating
5= VERY HARD: breathing labored, very difficult to keep going, sweating heavily

These last two questions refer to the overall mission.

18. What is the weight of the rucksack you are generally required to carry on a mission?_________

19. What mode of exercise do you most often employ during a mission?_________

A. walking
B. running
C. climbing
D. cycling
E. swimming
F. rucking

Thankyou for your time and consideration. Your comments and suggestions are gratefully encouraged.

____

____

____

____

____

____

APPENDIX E
NUTRITION QUESTIONNAIRE

USUAL FOOD INTAKE ON MISSIONS

1. Describe a usual day's diet/menu for the most typical mission you do.
   - Write the approximate time of day of each meal/snack you eat and then the food item and quantity of that food item that you eat.
   - write **MR** next to food items that are military rations and CP next to food items which you procure yourself commercially.
   - Use additional pages if necessary

Example:

TIME EATEN	QUANTITY	FOOD ITEM	MR or CP ?
0530	8 oz	coffee - black	MR
0600	1	granola bar	MR
0600	1 pkt	hot cocoa (mix 8 oz H_2O)	MR
1100	1	pouch bread	MR
1100	1 pkt	peanut butter	MR
1100	16 oz	H_2O	—
1500	1 pkt	Nut/Raisin Mix	MR

24-HOUR FOOD INTAKE   TYPE OF MISSION:___________

TIME EATEN	QUANTITY	FOOD ITEM	MR or CP ?

2. Do you normally maintain, lose, or gain weight on deployments?
If you gain or lose weight, how much? ______ pounds

3. Of the items listed in question 1, which foods/beverages do you pack and take with you on deployments?

FOOD ITEM	QUANTITY YOU PACK

4. Of the foods listed in question 1, which foods/beverages do you usually purchase or have sent to you while deployed?

FOOD ITEM	QUANTITY OBTAINED

DISTRIBUTION LIST

	NO. OF COPIES
Commander U.S. Army Aeromedical Research Laboratory ATTN: SGRD-UAX-SI Fort Rucker, AL 36362-5292	1
Commanding Officer Naval Health Research Center P.O. Box 85122 San Diego, CA 92186-5122	2
Director Defence Civilian Institute of Environmental Medicine 1133 Sheppard Avenue, West P.O. Box 2000 Downsview, Ontario, Canada M3M 3B9	2
CRAD/DSIS National Defence Headquarters Ottawa, Canada K1A OK2	1
Naval Submarine Medical Research Laboratory Medical Library, Naval Sub Base, Box 900 Groton, CT 06340	1
Food and Nutrition Board National Academy of Sciences Institute of Medicine 2101 Constitution Avenue Washington, DC 20418	3

Joint Chiefs of Staff 1
Medical Plans and Operations Division
Deputy Director for Medical Readiness
ATTN: RAD Smyth
Pentagon, Washington, DC 20310

Office of Undersecretary of Defense for Acquisition 1
ATTN: Environmental and Life Sciences
Room 3D129
Pentagon
Washington, DC 203101-3100

Office of the Assistant Secretary of Defense 2
Health Affairs
ATTN: Medical Readiness
Washington, DC 20310-1200

Office of the Assistant Secretary of Defense 1
Acquisition and Logistics
ATTN: OASD(A&L)SD
Washington, DC 20310-1200

HQDA (DALO-TST) 1
Washington, DC 20310-2300

HQDA
Assistant Secretary of the Army for Research, 1
Development and Acquisition
ATTN: SARD-TM
Pentagon
Washington, DC 20310

HQDA
Office of The Surgeon General 1
ATTN: DASG-RDZ/Executive Assistant
Room 3E368
Pentagon
Washington, DC 20310-2300

HQ U.S. Marine Corps 1
Code LFS-4
Washington, DC 20380-0001

Commanding Officer 1
Navy Food Service Systems Office
901 M Street, SE
Washington, DC 20374-5049

Commander 1
Walter Reed Army Medical Center
ATTN: Nutrition Care Division
Washington, DC 20307-5000

Director 1
Walter Reed Army Institute of Research
Washington, DC 20307-5100

Commanding Officer 1
Naval Aerospace Medical Institute - Code 32
Naval Air Station
Pensacola, FL 32508-5600

U.S. Naval Aerospace Medical 1
Institute Library - Code 03L
Building 12953
Pensacola, FL 32508-5600

Commanding Officer 1
U.S. Naval Aerospace Medical Research Laboratory
Naval Air Station
Pensacola, FL 32508-5700

Medical Library - Code 185 1
U.S. Naval Hospital
6000 West Highway 98
Pensacola, FL 32512-0003

Commandant 1
U.S. Army Physical Fitness School
ATTN: ATZB-PFS
Fort Benning, GA 31095-5000

Commander 1
HQ U.S. Army Forces Command
Office of the Surgeon
ATTN: FCMDFJ-1
Fort McPherson, GA 30330-5000

Commander 1
U.S. Army Soldier Support Center
Fort Benjamin Harrison, IN 46216

Commander 1
U.S. Army Combined Arms Center
ATTN: ATZL-TIE

Fort Leavenworth, KS 66027-5130

Commander 1
U.S. Army Natick Research, Development and
Engineering Center
Natick, MA 01760-5000

Commander 11
U.S. Army Natick Research, Development and
Engineering Center
ATTN:
SATNC-T/ SATNC-TF/ SATNC-TR/ SATNC-TI/ SATNC-TN /
SATNC-TL/ SATNC-TM/ SATNC-W/ SATNC-Y/ SATNC-P/
SATNC-MIL
Natick, MA 01760-5000

Commanding Officer 1
U.S. Navy Clothing and Textile
Research Facility
P.O. Box 59
Natick, MA 01760-0001

Commander 1
U.S. Army Environmental Hygiene Agency
Aberdeen Proving Ground, MD 21010-5422

Director 1
U.S. Army Research Laboratory
Human Research and Engineering
Aberdeen Proving Ground, MD 21005-5001

Commander 1
U.S. Army Test and Evaluation Command
ATTN: AMSTE-EV-S
Aberdeen Proving Ground, MD 21005-5055

Commander 1
U.S. Army Medical Research Institute of
Chemical Defense
ATTN: SGRD-UV-ZA
Aberdeen Proving Ground, MD 21010-5425

Commander 2
Naval Medical Research Institute
Bethesda, MD 20889

Commanding Officer Naval Medical Research and Development Command National Naval Medical Center/Building Bethesda, MD 20889-5044	1
Public Health Service National Institutes of Health Building 31, Room 4B63 Bethesda, MD 20892	2
Public Health Service National Institutes of Health Building 31, Room 4A21 Bethesda, MD 20892	1
Uniformed Services University of the Health Sciences ATTN: Department of Military and Emergency Medicine 4301 Jones Bridge Road Bethesda, MD 20814-4799	1
Uniformed Services University of the Health Sciences Department of Military and Emergency Medicine 4301 Jones Bridge Road Bethesda, MD 20814-4799	1
Commanding Officer Naval Medical Research Institute Bethesda, MD 20889	1
Commander U.S. Army Medical Research, Development, Acquisition and Logistics Command ATTN: SGRD-ZA/ SGRD-ZB/ SGRD-RML-S/ SGRD-PLC/ SGRD-PLE Fort Detrick Frederick, MD 21702-5012	2 ea office
Commander U.S. Army Biomedical Research and Development Laboratory Fort Detrick Frederick, MD 21702-5010	1

Commander 1
U.S. Army Medical Research Institute of
Infectious Diseases
ATTN: SGRD-UIZ-A
Fort Detrick
Frederick, MD 21702-5010

Commander 1
U.S. Army Medical Materiel Development Activity
Fort Detrick
Frederick, MD 21702-5009

Commander 1
U.S. Army Medical Materiel Activity
Fort Detrick
Frederick, MD 21702-5001

Commander 1
U.S. Army Aviation and Troop Command
ATTN: AMSAT-B-DSL
4300 Goodfellow Boulevard
St. Louis, MO 63120-1798

Commander 3
John F. Kennedy Special Warfare Center
ATTN: AOJK-CD-TE/ AOJK-CD-CS/ DOCD-M-L
Fort Bragg, NC 28307-5000

United States Department of Agriculture 1
ATTN: ARS Human Nutrition Research Center
P.O. Box 7166 University Station
2420 2nd Avenue North
Grand Forks, ND 58202-7166

Dietitian 1
Staff and Faculty - Cadet Mess
U.S. Military Academy
West Point, NY 10996

Commander 1
Armstrong Medical Research Laboratory
Wright-Patterson Air Force Base, OH 45433

Commander 1
U.S. Army War College
Carlisle Barracks, PA 17013

Commander | 1
U.S. Army Military History Institute
ATTN: Chief, Historical Reference Branch
Carlisle Barracks
Carlisle, PA 17013-5008

Commander | 1
U.S. Air Force School of Aerospace Medicine
Brooks Air Force Base, TX 78235-5000

Strughold Aeromedical Library
Document Services Section
2511 Kennedy Circle
Brooks Air Force Base, TX 78235-5122

Commander | 1
U.S. Air Force School of Aerospace Medicine
Brooks Air Force Base, TX 78235-5000

HQ AFMSC | 1
ATTN: SGPA
Brooks Air Force Base, TX 78235

Commander | 1
U.S. Army TRADOC
ATTN: ATCT-PO/Combined Arms Test Activity
Fort Hood, TX 76544

Commandant | 2
Army Medical Department Center and School
ATTN: HSMC-FM, Building 2840
Fort Sam Houston, TX 78236

Commandant | 3
Army Medical Department Center and School
ATTN: AHS-CDM/ HSHA-CDM/ HSHA-CDS
Fort Sam Houston, TX 78234-6100

Commandant | 1
Army Medical Department Center and School
ATTN: Director of Combat Development
Fort Sam Houston, TX 78234-6100

Commandant | 1
Army Medical Department Center and School
ATTN: Chief Librarian, Stimson Library
Building 2840, Room 106

Fort Sam Houston, TX 78234-6100

Commander Brooke Army Medical Center ATTN: HSHA-MR (Nutrition Care Branch) Fort Sam Houston, TX 78234-6100	2
Commander U.S. Army Institute of Surgical Research Fort Sam Houston, TX 78234-5012	1
Defense Technical Information Center ATTN: DTIC-DDA Alexandria, VA 22304-6145	2
Commander U.S. Army Materiel Command ATTN: AMCDE-S Alexandria, VA 22333	1
Commander U.S. Army Research Institute for Behavioral Sciences 5001 Eisenhower Avenue Alexandria, VA 22333-5600	1
Commander U.S. Army Operational Test and Evaluation Agency ATTN: CSTE-ZA Park Center IV, 4501 Ford Avenue Alexandria, VA 22302-1458	1
Director of Biological and Medical Sciences Division Office of Naval Research - Code 141 800 N. Quincy Street Arlington, VA 22217	1
HQDA (DASG-ZA) 5109 Leesburg Pike Falls Church, VA 22041-3258	1
HQDA (DASG-MS) 5109 Leesburg Pike Falls Church, VA 22041-3258	1
HQDA (DASG-DB) 5109 Leesburg Pike Falls Church, VA 22041-3258	2

HQDA (SGPS-FP) 5109 Leesburg Pike Falls Church, VA 22041-3258	2
HQDA (SGRD-ZS) 5109 Leesburg Pike Falls Church, VA 22041-3258	1
HQDA (SGPS-PSP/Preventive Medicine Consultant) 5109 Leesburg Pike Falls Church, VA 22041-3258	1
Commander U.S. Army Health Facility Planning Activity 5109 Leesburg Pike Falls Church, VA 22041-3258	1
Commandant U.S. Army Quartermaster Center and School ATTN: ATSM-CDT/ ATSM-SFS-FM/ ATSM-CES Fort Lee, VA 23807	3
Director Army Troop Support Agency ATTN: DALO-TAF/ DALO-TAF-F Fort Lee, VA 23801	2
Commander U.S. Army Training and Doctrine Command ATTN: ATCD-S Fort Monroe, VA 23651	1
Commander U.S. Army Training and Doctrine Command ATTN: ATMD (Office of the Surgeon) Fort Monroe, VA 23651-5000	1
Commanding Officer Navy Environmental Health Center 2510 Walmer Avenue Norfolk, VA 23513-2617	1
Project Officer, Army Field Feeding ATTN: AMC-PM-CIE 14050 Dawson Beach Rd Woodbridge, VA 22191-1419	3